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International bioenergy trade—A review of past developments in the liquid biofuel market

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ABSTRACT

Policies aimed to promote biofuels locally had tremendous effects on global market developments across the past decade. This article develops insights into the interaction of these policies and market forces via a comprehensive collection and analysis of international production and trade data. It shows that world biofuel production and trade has grown exponentially: from below 30 PJ in 2000 to 572 PJ in 2009 for biodiesel; from 340 PJ in 2000 to over 1540 PJ in 2009 for fuel ethanol. The EU has dominated world biodiesel, whereas the US and Brazil have led fuel ethanol production. World net biofuel trade reached 120–130 PJ in 2009 and was directed towards the most lucrative markets. For biodiesel, this has been the EU whose imports rose to 92 PJ in 2008 and remained at 70 PJ in 2009. Regarding fuel ethanol, both the US and the EU have been prime destinations for competitively priced exports, the vast majority of which originated in Brazil. International biofuel trade is both supply and demand driven. The demand side was shaped by support policies which generally increased the domestic market value of biofuels. Trade developed wherever these policies/prices were not accompanied by respective measures. It is found that import duties largely influenced trade volumes, whereas trade routes were mainly driven by tariff preferences. Trade regimes appear to have been designed and adapted unilaterally along national interests causing market disruptions, trade inefficiencies and disputes. To avoid these, it is important to explicitly consider international trade implications of national trade policies. A prerequisite is to improve the understanding of the underlying, complex and interwoven links within the market. The current lack of adequate, homogeneous, international reporting of biofuel production and trade statistics could be bridged via internationally standardized custom clarifications. Trade factor interrelations also need to be investigated further.

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1. Introduction, problem definition, outline

Numerous governments around the world (primarily in OECD countries) have supported the market introduction of biomass for energy purposes (bioenergy) across the past decade. Domestic bioenergy policies indubitably had a tremendous effect on global markets. Nowadays, more bioenergy than ever before is sourced from abroad and procurement areas – especially of large scale producers and traders – span the globe.

This trend is bound to continue. Though potential studies vary in terms of exact amounts (see e.g. [1,2] for a review), given favorable development, it is clear that several hundred EJ per annum of bioenergy could be provided in the future global energy supply. Some regions are estimated to have a bioenergy potential that will exceed their national demand; foremost developing countries, while others are expected to become net importers (see e.g. [3,4]). Thus, an increasing role of bioenergy in the global energy matrix is inevitably intertwined with large-scale international trading activities of bioenergy commodities.

Yet the international bioenergy market and trade developments are still in their infancy and strongly linked to the support and trade policies. Past changes in the policy framework have shown how vulnerable these markets and trade patterns still are. Several studies have thoroughly analyzed the early market stages, initial trade volumes, as well as barriers to trade and solutions to overcome them (see e.g. [5–10]). These studies however have not evaluated how the interaction of these domestic policies steered global trade streams towards different markets, in particular in connection to underlying trade policies and additional market forces, over an extended period of time. To do so, a comprehensive collection and scientific analysis of international trade data is indispensable but also lacking (see Heinimö and Junginger [5] for a first rough estimate). Market data is scattered and, where available, as e.g. via (supra-) national and international institutions (e.g. Eurostat, USDA, UN), organizations (e.g. FO Licht) or associations, estimations vary. This paper aims to provide such analysis. Due to the complexity and differences between the markets of liquid and solid biofuels, this study is split into two (separate yet combined) articles, the first of which deals with liquid biofuels.[3]

The biofuel market has shown an exponential growth in global production and trade across the past decade. It is strongly linked to other sectors (agriculture in particular) and faces significant market disturbances some of which have led to various inefficiencies in the past. Due to the pace of this market development, a methodological assessment and understanding of the numerous influencing factors is needed to reduce uncertainties and risks for those involved. This would primarily apply to policy makers in terms of e.g. target achievements (including the safeguarding of sustainability standards) and investors.

The assessment is structured along the following research questions:

1. What were the key policies and economic/market forces that have shaped international trade in liquid biofuels within the past decade?
2. How often were liquid biofuel trade routes altered in response to changes in policy and market environments? And, what can be learned from these changes?

The methodological approach to answering these questions is presented in Section 2. Section 3 outlines the chronological development of key policies and trade regimes in the focus regions. Section 4 provides qualitative and quantitative comparisons evaluating and describing trade volumes related to the respective policies and additional economic/market drivers. The section identifies and – where possible – quantifies the impact of policies on international bioenergy trade, on the key commodities, and on trade routes. Based on this analysis, a methodological approach for the calculation of the world net liquid biofuel trade within the past decade is suggested and tested in Section 5. Section 6 combines the key results regarding the policy and market interlinks before the paper closes with a reflection and conclusion. Additional details on underlying data and related assumptions for the analysis are presented in Appendix A.

2. Methodology

The paper starts with a collection of key biofuel and trade policies across major markets. Commodities in focus include biodiesel, vegetable oils, and fuel ethanol. To explain how policies and economic factors impact markets, we then describe the chronological market developments using anecdotal evidence based on previously published scientific work as well as additional literature and insights from policy makers, traders, and industry representatives. The evaluation prioritizes the main aspects, i.e. the main influencing factors per policy and region depending on the traded biofuel volumes. The link between policies and trade flows is further established by highlighting policy changes in key markets and their effects on trade. The paper does not reflect on the effectiveness or efficiency of biofuel policies.

A fundamental part of the analysis is the collection and presentation of robust data on international biofuel production and trade across the past decade. Data was derived and compared between various sources including government statistics [11–23], international organizations [24,25], industry associations [26–42],

[3] I.e. within the context of the article, 'biofuels' only refer to liquid biofuels if not otherwise stated.

and other market information sources [43–48]. The starting point consisted of a review of global biofuel production data. Wherever possible, industry data (via associations and/or market information sources) was selected and compared to government statistics (see Appendix A for a detailed discussion on production data selection). Secondly, import and export data was collected; primarily via government trade statistic databases, but also from associations and market information sources. Trade flows were cross-checked, i.e. declarations of import volumes were compared to the respective declarations of export volumes by exporting countries. Key challenges encountered were varying commodity codes and definitions across different national statistics and a general lack of end-use specification—in particular regarding ethanol. Respective assumptions in order to combine and/or compare trade flows had to be made. Wherever necessary, these are laid out in the paper. In general, most sources provide data for several consecutive years; where not, respective assumptions are outlined.

3. Policies and trade regimes

Support policies targeting biofuels can take on various forms and aim at different stages along the biofuel value chain. They can either push (e.g. mandates) or pull (e.g. tax incentives) biofuels into the market. It is suggested to categorize biofuel support policies in the following ways (see also Junginger et al. [10]):

- *Promotion of domestic consumption* via consumption mandates (for biofuel content or minimum GHG savings through biofuels) or incentives (e.g. tax exemptions for the biofuel at the pump or promotion of dedicated biofuel vehicles),
- *Promotion of domestic production* via production mandates; investment support (e.g. loans, grants, direct subsidies) for production facilities, demonstration projects, infrastructure or R&D; feedstock support or tax incentives (e.g. excise tax exemption), and
- *Trade related measures* either shielding local production (and thus market prices) through protective measures (e.g. import tariffs, eligibility requirements within biofuels quota, standards) or preventing exports by installing export tariffs.

Most of the time countries implement a portfolio of measures, thus covering several of the categories and sub-items listed.

3.1. European Union (EU)

3.1.1. Policies

Biofuel production in the EU neither began nor expanded on a significant scale until the 1990s (see [49,50] for a detailed economic evaluation of EU liquid biofuels policy). Throughout the 1990s, the Common Agricultural Policy (CAP) (indirectly) supported biofuel production through guaranteed minimum prices, per hectare payments, and compensatory payments for set-aside land that could nevertheless be used for biofuel feedstock production. In addition, the CAP reform in 2003 introduced a crop premium for the production of energy crops on basic land.

2003 marked a critical year for the EU biofuels industry as policy initiatives that had been extensively discussed on EU-level (see e.g. [50,51] for an overview) and also partially applied in individual Member States (MS)[4] by then were implemented into EU legislation. The Biofuels Directive 2003/30/EC [52] introduced biofuel quotas by energy content thus requiring MS to guarantee a minimum market share to biofuels. The indicative targets were 2% by the end of 2005, 5.75% by 2010, and 10% by 2020. To help MS meet these targets, the EC allowed MS to exempt or reduce excise duties on biofuels through the Energy Tax Directive 2003/96/EC [53] granted their authorization according to state aid rules. Even though the tax incentives and quotas caused an increase in domestic biofuel production and imports (see Figs. 2 and 8), the 2005 biofuel quota was not met on EU-level. By 2008 it was also clear that the 2010 target was unrealistic (see e.g. [54]), and as a result the EC revised its biofuel policy. The revision was also partly triggered by the ongoing international debate around the sustainability of biofuels which gained momentum in 2007 and was largely triggered by rising prices for agricultural commodities.

The European Commission's (EC) current approach is reflected in the Renewable Energy and Fuel Quality Directive. The Renewable Energy Directive 2009/28/EC (RED) [55] requires – among others – an overall 10% share of renewable energies in final energy demand within the transport sector for all MS by 2020. It also outlines mandatory sustainability criteria (see Art. 17–19) encompassing minimum savings of greenhouse gas emissions as well as additional environmental and also partially social criteria affecting production. Such criteria include, e.g. restrictions on the types of land that may be converted for the production of feedstock.[5] As of November 2010, the restrictions addressing the conversion of land only covered direct land-use change—a future revision to account for potential indirect land-use change is foreseen. Any biofuels and bioliquids that serve to fulfill the MS' 10%-target have to comply with these RED requirements.

The Fuel Quality Directive 2009/30/EC (FQD) [56] aims at a 6% reduction of greenhouse gas emissions from fuels consumed in the EU by 2020. It introduces technical regulations for petrol, diesel, and gas-oil (e.g. maximum levels of oxygen, ethanol, or ETBE) and identical sustainability requirements as the RED. In addition, there are several technical industry standards such as EN 228 (petrol), EN 590 (diesel), EN 14214 (biodiesel), prEN 15376 (ethanol as a blending component for petrol), and CWA 15293 (E85). The FQD and the technical standards can be seen as potential non-tariff barriers to trade; though at the same time they provide consistency and certainty for both producers and consumers [50]. There are also ongoing negotiations on an international level to harmonize technical standards. The EU, the USA, and Brazil have e.g. published a tripartite white paper on internationally compatible biofuel standards.[6]

3.1.2. Trade regimes

EU biofuel trade regimes are governed through various regulations defining import duties and tariff preferences. They are differentiated between commodities and by country of origin. Preferential access to the EU market is given for goods of developing countries under the Generalized System of Preferences (GSP),[7] the GSP+,[8] and bi- or multi-lateral agreements such as the Cotonou Agreement (for African, Caribbean, and Pacific states), the Everything But Arms Initiative (for least developed countries), or the Economic Partnership Agreement.

EU biodiesel trade regimes were adapted several times within the last decade. Until 2007, biodiesel was traded as 'other

[4] Tax exemptions for biodiesel were granted in Austria, Germany (only B100), Sweden, Poland, and Slovakia prior to 2003.

[5] Further information on the practical implementation of the criteria has been published by EC in its Communication 2010/C 160/02.

[6] http://ec.europa.eu/energy/renewables/biofuels/doc/standard/2007_white_paper_icbs.pdf [July 8th, 2010].

[7] These conditions are generally valid for a period of three years. The former Regulation 980/05 – covering the period from 01.01.2006 to 31.12.2008 – was amended by the current Regulation 732/08 which is valid until 31.12.2011.

[8] A special arrangement for sustainable development and good governance which offers additional tariff reductions to support vulnerable developing countries in their ratification and implementation of international conventions in these areas.

Table 1
EU and US import tariffs for selected commodities (EU data: [67]; US data: [65]).

	Commodity	Code	Import duty	Additional duties/taxes	Tariff preference: 0.0%
EU	Fatty-acid mono-alkyl esters (FAMAE)	3824.90.91	6.5% (ad v.)	US: ADD and CVD	GSP, GSP+, EPA
	Undenatured ethyl alcohol of an alcoholic strength by volume of 80% vol or higher	2207.10.00.10	0.2536 US$/l (0.192 €/l)	–	GSP+, EPA, Caribbean
	Ethyl alcohol and other spirits, *denatured*, of any strength	2207.20.00.10	0.1347 US$/l (0.102 €/l)	–	
USA	Fatty substances of animal or vegetable origin and mixtures thereof	3824.90.40	4.6% (ad v.)	–	As for ethanol with the exception of Argentina and Indonesia being excluded under the GSP
	Biodiesel and mixtures thereof, not containing or containing less than 70% by weight of petroleum oils or oils obtained from bituminous minerals	3824.90.40.30			
	Undenatured ethyl alcohol of an alcoholic strength by volume of 80 percent vol. or higher (for fuel use)	2207.10.60 (.10)	2.5% (ad v.)	0.1427US$/l[a] (0.108 €/l)	CBI, CAFTA, ATPA, NAFTA, GSP Morocco, Jordan, Singapore, Chile, Australia, Bahrain,
	Denatured ethyl alcohol of an alcoholic strength by volume of 80 percent vol. or higher (for fuel use)	2207.20.00 (.10)	1.9% (ad v.)	0.1427US$/l[a] (0.108 €/l)	Oman, Peru, Israel,

ADD: anti-dumping duties of 91 to 262 US$/tonne (i.e. 68.60–198 €/t) depending on company; CVD: countervailing duties of up to 313 US$/tonne (i.e. 237 €/t) depending on company; ATPA: Andean Trade Preference Act (Bolivia, Colombia, Ecuador, Peru); CBI: Caribbean Basin Initiative (e.g. Bahamas, Dominica, Haiti, Jamaica, Panama, Trinidad and Tobago); CAFTA: Central America Free Trade Agreement (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Dominican Republic); GSP: Generalized System of Preferences (see http://www.ustr.gov/trade-topics/trade-development/preference-programs/generalized-system-preference-gsp for more details); NAFTA: North American Free Trade Agreement (Canada, Mexico).

[a] Fuel ethanol taxes are covered by reporting number 9901.00.50 with reference to 2207.10.60 and 2207.20.00 respectively.

chemicals' (CN[9] 3824.90.98). That category however consists of several sub-categories and it remains unclear which of these were primarily used for biodiesel imports. As of 2008, the code ceased to be listed, while a new code for fatty-acid mono-alkyl esters (FAMAE) was created.[10]

In March 2009, the EU established anti-dumping and countervailing duties against US biodiesel imports under Regulations 598/09 and 599/09 (see Section 4.1). With this, five additional biodiesel categories were added. In August 2010, the tariff lines were revised again in accordance with the Regulations 720/10 and 721/10 dealing with the circumvention of the countermeasures by exporting US biodiesel via Canada and Singapore. It is important to note that all tariff lines apply to biodiesel concentrations of B20 and higher. As a result, B19 (and lower biodiesel concentrations) do not fall under the EU biodiesel tariffs. Apart from the effect this might have on trade, it also implies that trade of B19 (and lower concentrations) is not yet recorded by Eurostat trade statistics (which rely on the codification). In addition, Eurostat does not disseminate statistics of CN codes above eight digits [57]. Hence, no trade data is publicly obtainable for the biodiesel categories established in March 2009.[11]

Trade regimes regarding vegetable oils are similar to those for biodiesel. A duty of 3.2% (ad valorem) is imposed on imports of vegetable oils that compete with EU vegetable oil production, e.g. rapeseed, sunflower, and soy oil. Tariff preferences are given to GSP and GSP+ countries. Soy beans, rapeseeds, and also palm oil enter the EU duty free.

Contrary to the introduction of special codes for the import of biodiesel, fuel-grade ethanol is still imported under the classification of denatured and undenatured ethanol. Tariffs were set via Regulation 2204/99 and have been applied since 2000. According to [50], custom experts claim that due to the various end-uses (industrial, pharmaceutical, and beverage) it would be too difficult to verify the purpose of the imported ethanol. Thus no further itemization has since been made.

Tariff preferences regarding ethanol changed with the introduction of Regulation 980/05 which excluded a range of beneficiaries (e.g. Pakistan) from having unlimited duty-free access to the EU market [50]. Brazil had already been exempted from ethanol tariff preferences for years at that time. As Table 1 shows, tariff preferences are currently given to developing countries under the GSP+ and the Economic Partnership Agreement (EPA). They also apply to Caribbean states and a range of other countries.

3.2. United States of America (USA)

3.2.1. Policies

The structure of US biofuel support policies is similarly complex (as in the EU) since the implementation of federal targets and policies varies from state to state. The main developments are summarized in this section. Detailed descriptions and evaluations of US biofuel support history can be found in literature (e.g. [58–60]).

In 2005, the Energy Policy Act [61] was passed which contained a Renewable Fuels Standard (RFS1) prescribing the production of 7.5 billion gallons of biofuels by 2012. Around the same time, more

[9] CN stands for Combined Nomenclature.

[10] Analysis of trade data by Eurostat [13] revealed that this change in import classification had further implications. First, the old 2008 code contains larger trade volumes and countries of origin than the newly created one. Secondly, the previous code also includes trade volumes from countries which are negligible regarding their biodiesel exporting activities (e.g. Algeria). Nevertheless both categories impose the same import duties and preferential tariffs.

[11] I.e. CN 1516.20.98.20 (animal or vegetable fats, esterified or hydrogenated), CN 1518.00.91.20 and CN 1518.00.99.20 (animal or vegetable fats excluding 1516), CN 2710.19.41.20 (petroleum oils); and also CN 3824.90.97.87 (binders and chemical products) which was again closed in August 2010.

than 25 US States partially or completely banned methyl tertiary butyl ether (MTBE) as a petrol additive due to its ability to adversely affect drinking water [62]. MTBE was largely replaced by ethanol [62] causing the 2012 production target to be exceeded already by 2008 [54].

In 2007, the Energy Independence and Security Act [63] amended the RFS1. The current Renewable Fuels Standard (RFS2) demands a 36 billion gallon biofuels production target by 2022. The target is split into sub-targets for ‘conventional’ and ‘advanced’ biofuels depending on their GHG saving range. Conventional biofuels (>20% GHG savings) are allowed to contribute 15 billion gallons and will – according to the USDA [23] – be met primarily through corn starch ethanol. Advanced biofuels (>50% GHG savings) shall cover the remaining 21 billion gallons. The biodiesel share among the advanced biofuels cannot be less than 1 billion gallons and the cellulosic biofuel share must also be at least 16 billion gallons. The final rulemaking process of the RFS2 took until early 2010 due to complaints by the US biofuels industry leading to a reexamination of the GHG calculations. Under the final rule (effective as of July 2010), corn starch based ethanol counts as conventional biofuel while Brazilian ethanol is attributed the advanced biofuel status.

Prior to the establishment of the first national biofuel production targets under the Energy Policy Act, the American Jobs Creation Act [64] introduced Volumetric Excise Tax Credits (VETC) for the blending of fuel ethanol and biodiesel (see Table 13, Appendix A for details). VETC make up the single largest subsidy to biofuels in the US [60]. Since they are neither capped nor linked to oil price developments, they have risen in correlation to the amount of domestic consumption [60]—as well as exports (see Section 4.1). Additional subsidies are provided in the form of capital investment support via loans, grants, and guarantees for the construction of biofuel plants, governmental investment in infrastructure for transport, storage, and distribution of biofuels, and crop subsidies esp. maize [54,58,60].

3.2.2. Trade regimes

As is the case in the EU, US biofuel trade regimes are differentiated between commodities and by country of origin. Preferential access to the US market is granted in a similar way as in the EU, i.e. under a GSP for developing countries, a special rate for least developed countries, and rates under specific trade agreements such as the North American Free Trade Agreement (NAFTA) or the Caribbean Basin Initiative (CBI).

The US has one code for biodiesel (HS 3824.90.40.30)[12] which applies to blends of B30 or higher and imposes a 4.6% ad valorem duty on imports from countries with which the US does not have a free-trade agreement [65,66]. Import duties for vegetable oils and biodiesel feedstock apply largely to commodities competitive to local production with the exception of soybeans, which are duty free.

Similar to the EU, fuel ethanol trade has been earmarked under codes for denatured and undenatured ethanol for non-beverage purposes for years. Contrary to the EU however, the US government has used (and published) sub-codes for fuel ethanol since 2008 (see Table 1). US ethanol production is protected from international competition through a 2.5% ad valorem rate for undenatured and a 1.9% ad valorem rate for denatured ethanol (see Table 1). Some countries can import ethanol duty free as long as they stay below a quota set by the US International Trade Commission each year [58]. Since imported ethanol could still quality for the excise tax credit within the US, an additional duty of US$ 0.1427 per liter is leveled on fuel ethanol imports (see HTS code 9901.00.50). Interestingly, this practice is not applied to biodiesel imports.

3.3. Rest of the world

3.3.1. Key policies and markets for biodiesel and vegetable oil production and trade

Biodiesel markets are very closely linked to vegetable oil and oilseed/feedstock markets. The three largest fractions in global vegetable oil production in 2008 were palm, soybean, and rapeseed oil (see Rosillo-Calle et al. [68] for a detailed assessment of vegetable oil markets in regards to biodiesel). The major exporting countries of these commodities in the last years were Indonesia and Malaysia for palm oil, Argentina and Brazil for soybean oil, and Canada for rapeseed oil. Among these, key biodiesel exporting countries are yet only Indonesia, Malaysia, and Argentina.

In Brazil, the government introduced a mandatory biodiesel quota of 2% in 2008—which was progressively increased up to a 5%-blending level by 2010 [68]. Biodiesel production is encouraged through purchase auctions (for the local market), tax reductions/exemptions, and producers are shielded by a 14% biodiesel import tariff through the Common External Tariff of Mercosur [54,68,69]. The majority of biodiesel is based on soybean oil [68], though the share of tallow is increasing [26]. Brazilian exports have been marginal in the past years since the prices paid to producers under the national auctioning system are noticeably higher than international prices [26]. In addition, the industry is comprised of many small and medium-sized plants located in-land, rather than large scale producers near or within ports—as e.g. in Argentina.

Unlike Brazil, Argentinean biodiesel production has been export-oriented from the beginning (see Lamers et al. [70] for a detailed market assessment). The agricultural sector generates a significant income of foreign exchange for the country; an effect even more relevant after the 2002 economic downturn. Currently, more than 50% of all Argentinean exports are of agricultural origin [70]. Nevertheless, in order to maintain low internal food prices, an export tax is imposed on exports of agricultural origin. This results in biodiesel export taxes to be around 18.5% lower than for soybean oil, thus encouraging biodiesel exports [70]. In addition, biodiesel producers are granted tax exemptions. Even though Argentina has introduced a 5%-minimum blending requirement for biodiesel, its future production is assumed to be sufficient to further increase biodiesel exports (see Section 4.1).

Rising fossil fuel prices, increasing dependence on fuel imports, and a strong domestic palm oil sector led the Indonesian government to embrace a national policy for biofuels as part of its National Security Act in 2006, which aim at 10% biofuel consumption by 2010. Initially, the state-owned oil company Pertamina was forced to sell 5% biofuel blends (foremost palm oil derived biodiesel) to the local market by 2006 at the same price as (subsidized) fossil fuels [71]. Hence, the Indonesian government indirectly subsidized biofuel sales at the pump. Additional support was provided to biofuel infrastructure developments, plantation improvement, training, and R&D [71]. The rising international demand for biofuels and palm oil also sparked foreign direct investments in this field in Indonesia. External investors however seem to be primarily interested in the export markets due to the demand created by underlying policy measures as outlined in Sections 3.1 and 3.2. Eventually, rising prices for agricultural commodities and thus also biofuels caused Pertamina to reduce the biofuel contents in the fuel blends [71]. The government has recently changed its biofuel mandate to a 2.5% market share for biodiesel and a 3% market share for ethanol in the transport fuel sector by 2010.

[12] USDA trade data [21] can only be gathered for the code 3824.90.40.20 (Fatty Esters Animal/Vegetable/Mixture) regarding imports, and for code 3824.90.40.00 (Fatty Substances Animal/Vegetable/Mixture) regarding exports. Since the majority of these streams is biodiesel this approximation is deemed to be a sufficiently accurate data basis for the analysis.

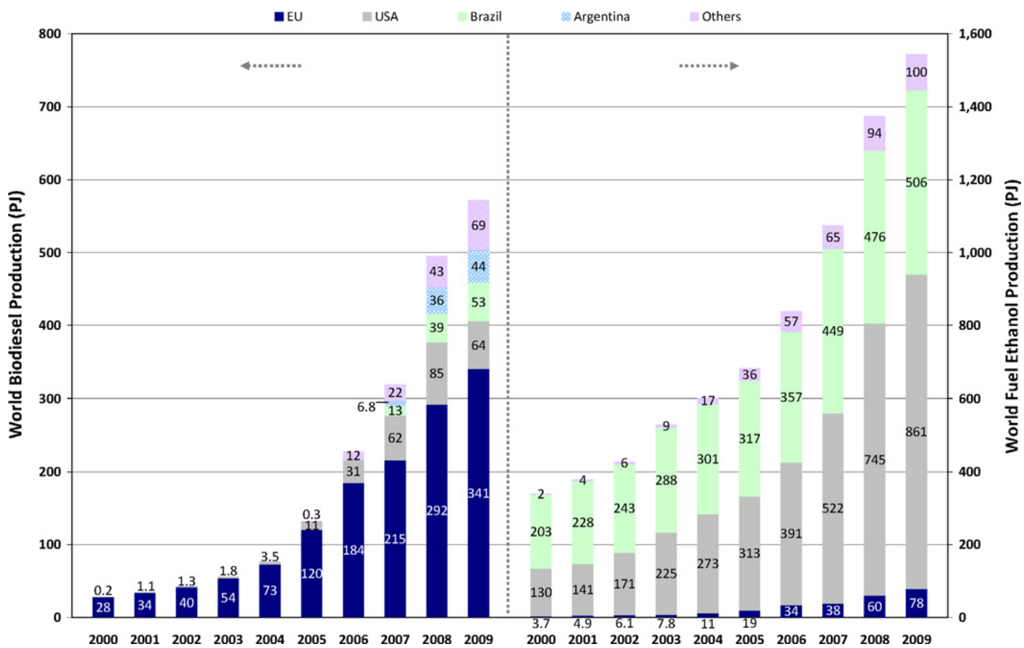

Fig. 1. Development of world biodiesel and fuel ethanol production between 2000 and 2009 in PJ (for data and calculation see Appendix A).

As was the case for Indonesia, the Malaysian government became significantly interested in palm oil derived biodiesel production around 2005/2006 (see Lim and Teong [72] for a more detailed description of the Malaysian biodiesel policy development). Contrary to Indonesia however, the Malaysian government has not yet introduced any blending requirements. Support to biodiesel producers has mainly been given in the form of low-interest loans and federal grants [73]. As in Indonesia, rising feedstock prices made the production of palm oil derived biodiesel less and less economically viable for the local (subsidized) transport fuel market in 2007. Since then, Malaysian biodiesel production has been increasingly focused on export to OECD countries.

3.3.2. Key markets for (bio-)ethanol production and trade

Brazil has been the world's leading (bio-)ethanol producer for decades and was only surpassed by the US in 2006 (see Section 4.2). Brazilian experience in ethanol production dates back to the 1930s. However, it was not until the establishment of government subsidies to the sugarcane and ethanol industry under the Brazilian Proalcool Program in 1975 that ethanol started to replace a significant share of petrol in transport fuel supply. Despite its controversy, Proalcool has become a role model for countries worldwide aiming at the establishment of domestic sugar cane based ethanol production.[13] Among others, key success factors were the existing know-how and infrastructure for sugarcane production, the involvement of all players along the value chain, the competitiveness with fossil fuels due to high production efficiency, the ability to make use of co-products [78], and the introduction of flex-fuel vehicles (FFV) guaranteeing a long-term ethanol demand (see e.g. [76]). At present, all petrol sold in Brazil contains a 20–25% ethanol share on volume basis—in addition to neat ethanol supplies [79]. Brazil has the capacity to significantly expand its production due to the availability of land, technology, capital, know-how, and a relatively cheap labor force [79]. Brazilian ethanol expansion has however met some international criticism due to its potential impact on land-use change and other sustainability concerns (see Smeets et al. [80] for a recent evaluation).

As can be observed from ethanol trade statistics (see Section 4.2 and recent reports from USDA FAS[14]), there are also numerous activities across Central and South America, most notably in Guatemala, Colombia, Peru, and Bolivia focusing on sugarcane based (fuel) ethanol production and export—mainly to the US and the EU.

On the demand side, potentially strong markets for fuel ethanol are also emerging in Asia and South America (see Walter et al. [79], pp. 734f for a more detailed review). Japan has one of the highest global petrol consumption rates and lacks the conditions to produce such ethanol domestically on a large scale [79]. It could become a major importer of biomass based fuel ethanol (on the pre-condition of introducing effective biofuel support measures). China has already been importing increasing amounts of fuel ethanol over the past years (see e.g. [25]). According to Walter et al. [79], the country has E10 requirements in place in nine provinces and its ethanol industry focuses largely on non-food feedstock material.

4. International market developments

4.1. Biodiesel and vegetable oil

As shown in Fig. 1, there has been an exponential growth of global biofuel production in the past decade (see Appendix A for a detailed presentation and discussion of underlying data, assumptions, and calculations). While world biodiesel production was below 30 PJ in 2000 and reached around 572 PJ in 2009, global fuel ethanol production grew from just below 340 PJ in 2000 to over 1540 PJ in 2009. Clear distinctions between the two markets include: different geographic developments connected primarily to the different transport fuel demands; biofuel and agricultural policies of the respective countries/regions; and interests of the respective market players.

Since diesel has been the dominating fuel in final road transport consumption in the EU over the past decade (see Eurostat data in [27]), biofuel production has largely been focused on biodiesel. In

[13] The Proalcool Program has been described and evaluated in numerous studies in the past (e.g. [74–77]).

[14] See Webpage http://gain.fas.usda.gov/Pages/Default.aspx [August 19th 2010] for details.

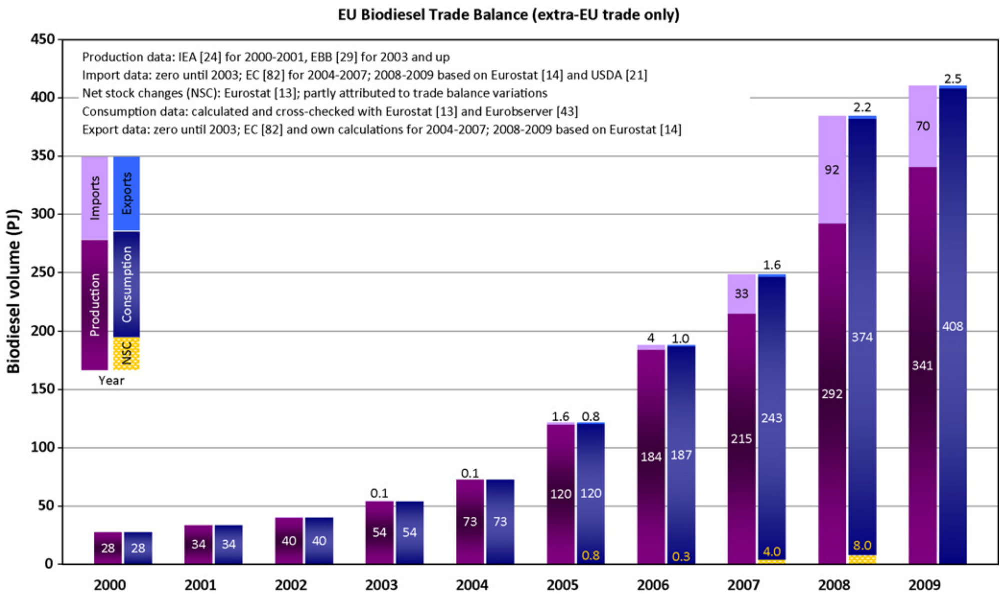

Fig. 2. EU biodiesel trade balance 2000–2009 in PJ (Data: [13,14,21,24,29,43,82]). *Note*: Eurostat [14] also offers a complete trade balance which includes intra-EU trade. To derive international trade data only, additional sources were used. Due to down-blending before customs and imports under other trade codings (e.g. 'Other chemicals'), EU biodiesel imports (i.e. FAMAE under CN 3824.90.91) as under Eurostat [13] show lower numbers (see Table 2) than EU imports combined with US export data, the approach used here.

particular, the introduction of the EU biofuels quota in 2003 – guaranteeing a minimum market share – and the option for MS to grant tax exemptions to biofuel production and consumption via the EU Energy Tax Directive stimulated this development.

Tax exemptions take on various forms across the EU, while the majority are aimed at final consumption.[15] Partial or total tax exemptions for biofuels at the pump have proven to be critical for their promotion in the EU; with the most successful examples being prevalent in countries where fossil fuel tax levels compensated for the additional production costs of biofuels as compared to fossil fuels [81]. Since 2008, mandates have accompanied or even replaced tax exemptions across the EU. This was partly to reduce MS' loss of fuel tax revenues, but also to provide long-term targets enhancing the predictability of market developments and thus reducing the risks of investments (and ultimately the interest rates of loans) for producers. Mandates though were found to be less appropriate for the promotion of a specific type of biofuel as fuel suppliers will opt to blend low cost biofuels (see Wiesenthal et al. [81] for a detailed comparison of mandates and tax exemptions). This policy change has been a key reason for the increasing amount of conversion capacity for both ethanol and biodiesel being installed in European harbors and connected inland waterways as they have access to (diverse and potentially cheaper) international biofuels/feedstock. Currently 18 MS have a mandate—16 of which also provide tax exemptions. Complementary policies to promote biofuels across the EU include direct support for producers, investment subsidies, or R&D programs.

Prior to 2008, EU biodiesel production and consumption was dominated by Germany (see [14]). The main reasons for the strong growth of the German market include tax exemptions for low and in particular neat biodiesel blends; early investment support provided on state level; existing know-how; and infrastructure regarding rapeseed oil production and processing. In 2007 however, Germany introduced a biofuel mandate that excluded tax exempted biofuels. Without the tax exemptions, neat biodiesel was not price competitive against fossil diesel fuel. As a result, the consumption of B100 plummeted outside the mandate and has been limited to the farm sector since 2008 (which is still eligible for tax exemptions until 2012).

EU biodiesel production capacity more than tripled since 2006 reaching about 20.9 Mtonnes (788 PJ) in 2009 [29]. The largest increase was identified around the North Sea and connected inland waterways (in particular France, Benelux, UK). While the total production also rose during this period, biodiesel production capacity utilization dropped from around 81% in 2006 to about 43% in 2009 (own calculations based on [29]). Reasons for this overcapacity may include: a very attractive market setting at the time of investment decisions and construction start while competition from overseas biodiesel imports was low; policy modifications; and a relatively slower consumption increase—partly related to concerns regarding the sustainability of biofuels. Another key aspect is the change in biodiesel market price (related to fossil fuel prices) and production costs (related to feedstock prices). The gap under current market and policy schemes appears too big to make a full use of existing conversion capacity economically viable. Obviously, overcapacity also leads to increased competition and has influenced the closure of (smaller, less vertically integrated, less efficient, remote, etc.) biodiesel plants in Germany, Austria, and the UK (see e.g. [16]).

The increasing share of competitively priced international (i.e. EU-external) imports in recent years is clearly visible in the EU biodiesel trade balance (see Fig. 2). It should be noted though that this trade balance varies across individual MS regarding international and EU-internal trade (see Eurostat [13,14] for details).[16] For example, EU-external imports to Germany remain marginal while they dominate the trade balances of the Netherlands and the UK, and take also large shares in France, Spain, Italy, and Austria [13,14]. The reasons behind this are diverse. First, biodiesel prices differ across the MS varying mainly due to different tax levels and under-

[15] The development of the EU biofuel market and policies can be observed via the individual Member State reports to the European Commission, available under: http://ec.europa.eu/energy/renewables/biofuels/ms_reports_dir_2003_30_en.htm.

[16] The specific trade differences between EU-internal and external trade depend on policies, prices, infrastructure, market interests, and other factors and are too numerous to be dealt with within the scope of this article.

Table 2
Third country EU27 imports (PJ) and tariffs (ad valorem) of biodiesel (CN 3824.90.91) in 2008–2010 (Data: [13,67] if not indicated otherwise).

	2008	2009	2010[a]	Tariffs 2008	Tariffs as of March 2009
United States	56.06	14.37	0.001	6.5%	ADD, CVD[b]
Argentina	2.88	32.16	37.85	0.0%	0.0%
Canada	0.00	5.28	6.17	6.5%	6.5%
Indonesia	5.85	5.95	9.57	0.0%	0.0%
Malaysia	1.43	4.65	2.87	0.0%	0.0%
India	0.00	0.93	2.83	0.0%	0.0%
Singapore	0.00	0.77	1.31	6.5%	6.5%
Others	0.84	0.37	0.96		
Total (as under Eurostat [13])	67.06	64.47	61.56		
US exports to EU[c]	81.1	19.7	9.2		
Estimated actual EU imports[d]	92.1	69.8	70.8		

[a] Extrapolation.
[b] ADD: anti-dumping duties of 91–262 US$/t (i.e. 68.60–198 €/t) depending on company; CVD: countervailing duties of up to 313 US$/t (i.e. 237 €/t) depending on company.
[c] USDA [21] data for commodities under HS 3824.90.40.00.
[d] US exports to EU [21] plus EU imports from other third countries [13].

lying biofuel policies. Secondly, some MS do not produce sufficient domestic feedstock (e.g. due to lack of suitable land or opportunity costs) and rather import oilseeds, vegetable oil, or biodiesel. By 2008, domestic biodiesel feedstock, i.e. rapeseed and waste oils contributed 57% and 8% respectively, while soybean and palm oil contributed 24% and 11% respectively (own calculations based on [13,14,45,46]).

A growing number of harbors in the Netherlands (Rotterdam, Amsterdam), Belgium (Antwerp), and other MS (Italy, UK, Spain) have become strategic biofuel hubs that deal with the import, crushing, production, blending and re-export of biofuels and their feedstock.[17] While they (re-) export globally, they mainly serve as a European entrance gate for biofuels. As Eurostat [13] data shows, EU-imports of biodiesel (i.e. FAMAE under CN 3824.90.91) from other MS arose to 78 PJ in 2008 and 116 PJ in 2009. About 38% of this volume originated in the Netherlands and 14% in Belgium, both of which are assumed to be primarily international imports. 22% of the volume was from Germany and is assumed to be mainly local production. The main destinations in both years were France, Poland, and the UK. Apart from having access to a variety of feedstock, biofuel producers located in ports can also benefit from lower import tariffs for feedstock in comparison to the respective biofuel and its cleavage products. In addition, economic operators in ports can make use of a 'custom's grey area' as they may handle commodities before or directly after declaring customs, thus further reducing/avoiding tariff payments.

The portfolio of international biodiesel imports into the EU (based on [13]) is clearly influenced by EU tariff regimes (see Table 2). US imports dominated until (March) 2009 and were replaced by imports from Argentina, Indonesia, and Canada. Apart from the US, Canada and Singapore, all significant import countries (see Table 2) were subject to a 0.0% tariff preference for biodiesel (under CN 3824.90.91).

As the data in Table 2 shows, the US has faced anti-dumping and countervailing duties since March 2009. The introduction of these duties on biodiesel originating in the US was originally aimed at counteracting the so-called 'splash-and-dash' practice or 'B99' effect. It was based on the excise tax credit (VETC) provided per volume of biodiesel blended with fossil fuel that was established in 2004 by the US Congress (see Section 3 and Table 13, Appendix A). The definition of 'blending' made it possible to receive the credit by adding only 0.1% of mineral oil. The resulting B99.9 biodiesel could be exported to Europe where the biodiesel would receive a second financial incentive through many MS's support schemes. In addition, it was even possible to import biodiesel from a third country to the US (also from Europe), claim the tax credit and then export the product, e.g. to Europe. This practice was commonly known as 'splash-and-dash'.

While the US Emergency Economic Stabilization Act of 2008 extended the credit until the end of 2009, it also partially eliminated the splash-and-dash practice by limiting the credit to biodiesel with connection to the US. Biodiesel imported and sold for export was not eligible for the credit effective retroactively as of May 2008 [83]. Nevertheless, US-produced biodiesel could still receive the credit, be exported to Europe and be eligible for European tax exemptions. Therefore, the EC imposed anti-dumping and countervailing duties on US imports—effective as of July 2009 under the Regulations 598/09 and 599/09, which reduced direct US imports significantly (see Table 2 and Fig. 3, as well as Figs. 9 and 10).

Though US biodiesel imports to the EU were primarily replaced by Argentinean biodiesel, it should be noted that US imports to the EU already consisted to a large extent of Argentinean biodiesel. As Table 3 shows, US imports from Argentina rose to almost 20 PJ in 2008 – the prime phase of the B99 effect – and dropped again to 3 PJ in 2009. A similar trend can be observed for Indonesia. This shows that the EU biodiesel market is more lucrative for international biodiesel traders since the commodity value across many EU MS seems to be higher than in the US (where biodiesel is still subsidized) and EU custom duties are lower for Argentina and Indonesia (both 0.0%) compared to the US (both 4.6%).

A surprisingly large share of biodiesel imports to the EU also came from Canada in 2009 (see Table 2). As Al-Riffai et al. [69] claim, some of the Canadian quantities have been detected to be of US origin, i.e. having received tax credits in the US and in Canada; a practice termed 'double-splash-and-go'. In June 2010, the European Biodiesel Board (EBB) filed a complaint with the EC stating that US subsidized biodiesel still enters the EU market via triangular trade with third countries (as e.g. Canada and Singapore) or through blends at B19 or lower thus avoiding EU tariff lines for biodiesel [28]. An investigation into the issue was launched by the EC in August 2010 (under EC Regulation 720/2010 and 721/2010). As trade data shows (see Table 2), the claims regarding Canada appear to be justified, though not so far regarding Singapore. Australia is currently also investigating US imports upon price dumping [84].

It should be noted that Eurostat [13] data listed in Table 2 does not reflect the whole biodiesel import into the EU. First, there are additional categories for which data is not reported publicly by Eurostat [57]; second, the EU customs code for FAMAE only cov-

[17] An extra-European example of such a biofuel hub is Singapore; other major biofuel harbors include e.g. Santos in Brazil and Rosario in Argentina (both primarily export oriented).

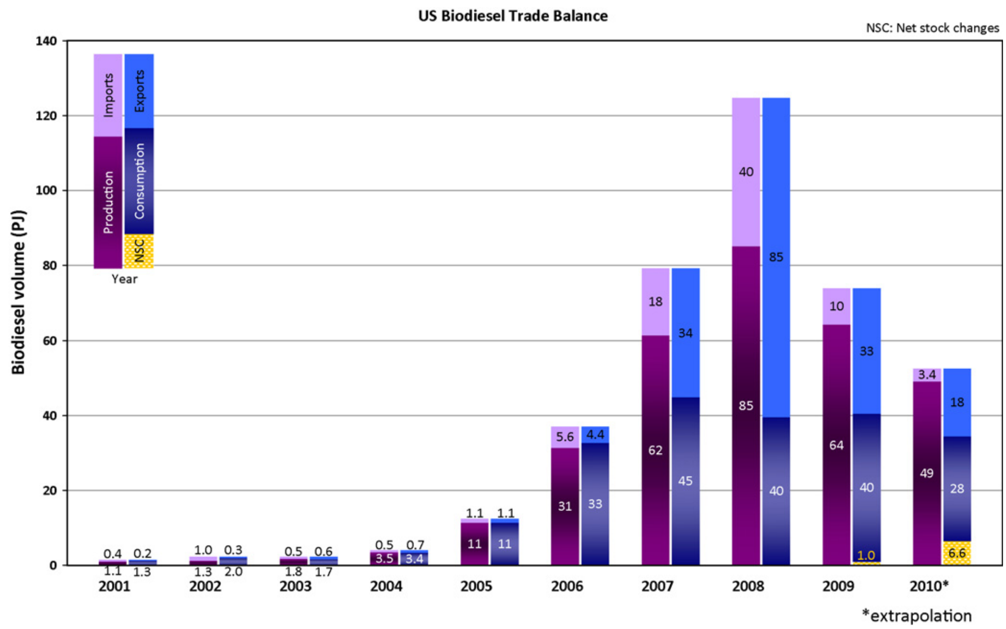

Fig. 3. US biodiesel trade balance 2000–2010 in PJ (Data: [12,21]).

ers blends of 20% biodiesel content and higher. As trade data of US exports of biodiesel (in concentrations of 30% biodiesel content or higher) show, the trade information gap fluctuates over the years between 4.5 and 25 PJ. This seems to support the claims by the EBB on the suspected practice of US B99 transport to EU ports, the down-blend to B19 within the port, and the declaration of B19 import. Hence, EU import data is estimated via US exports to the EU plus EU imports from other third countries (see Table 2).

From the early stages of the Argentinean biodiesel industry in 2006, large-scale production was mainly aimed at the EU market (see [70]; Section 3). In 2009, Argentina became the world's fourth largest biodiesel producer with an output of around 44 PJ (see Fig. 1). 43 PJ of this was exported in the same year [19,45]. As the Argentinean Renewable Energies Chamber [26] claims, biodiesel exports leave Argentina exclusively for Europe. The production is expected to grow further and reach between 70 PJ [19] and 86 PJ [45] in 2010. Since Argentina has implemented a 5% biodiesel blending requirement in 2010, exports are assumed to be between 46 PJ [19] and 56 PJ [45].

As outlined in EU and US trade tables (see Tables 2 and 3), both Indonesia and Malaysia play an increasingly important role in international biodiesel trade. While data on the production and export vary across different sources, FO Licht [45] and industry data from the Malaysian Palm Oil Board [34–36] seem to draw a robust picture. The production in both countries is mainly destined for export to the US and the EU (see Table 4). Domestic biodiesel consumption only plays a minor role in both Malaysia and Indonesia yet—reflecting the current policy status in both countries (see also Section 3.3.1). Malaysian biodiesel production and exports have increased steadily in recent years, while Indonesian production seems to be fluctuating slightly. While both Malaysia and Indonesia are rather new players on the global biodiesel market, they have a long history of palm oil production and trade.

4.1.1. Vegetable oils

The international production and consumption of vegetable oils increased constantly over the past ten years (see Rosillo-Calle et al. [68] for a detailed analysis of vegetable oil markets in regards to biodiesel). Across this period, net trade in vegetable oils alone (excluding oil grains other than soybeans) doubled (see Fig. 4). The largest shares are attributed to palm and soybean oil. The fastest growing segment is palm oil—especially due to its low pricing [85]. The second largest share is taken by soybeans and soybean oil with soybeans contributing the larger part to this growth. The growing trade in oilseeds is partly due to the fact that many countries with limited opportunity to expand oilseed production continued to invest in oilseed crushing capacity—such as China [86].

The key export destinations for Indonesian and Malaysian palm oil (which make up around 90% of the global market) include China, India, Pakistan, the EU, and the Middle East. Major trade routes for soybeans and soybean oil originate in Brazil, Argentina, and the US and are destined for markets in Asia (primarily China and India)

Table 3
US imports (PJ) and tariffs (ad valorem) of biodiesel (HS 3824.90.40.20) in 2006–2010 (Data: [21,65]).

	2006	2007	2008	2009	2010[a]	Current tariffs
Argentina		1.5	19.6	3.0		4.6%
Malaysia	2.0	4.7	2.3	2.8	0.3	0.0%
Canada	0.3	0.6	2.1	2.4	2.6	0.0%
Indonesia	0.9	6.7	10.1	0.5		4.6%
Singapore	0.1	1.2	3.7	0.4		0.0%
Others	2.3	2.9	1.7	0.6	0.5	
Total	5.6	17.6	39.6	9.7	3.4	

[a] Extrapolation based on data until June 2010.

Table 4
Biodiesel production and export from Malaysia and Indonesia vs. US and EU imports in 2006–2010 in PJ (Data: as indicated).

	2006	2007	2008	2009
Malaysia				
Production	2[a]–12[b]	4[a]–15[b]	7[a]–16[b]	9[a]–20[b]
Exports	1.8[c]–12[b]	3.6[c]–18.3[b]	6.9[c]–17.2[b]	8.6[c]–22.6[b]
US and EU imports from Malaysia[d]	1.96	4.72	3.78	7.45
Indonesia				
Production	1.8[a]–2.6[e]	4[a]–9[e]	3[a]–27[e]	3[a]–14[e]
Exports	0.9[a]–1.7[e]	3.0[a]–7[e]	3.0[a]–10.6[e]	2.6[a]–7.1[e]
US and EU imports from Indonesia[d]	0.92	6.73	15.98	6.40

[a] FO Licht [45].
[b] USDA [18].
[c] FO Licht [45]; MPOB [34–36].
[d] Trade data as reported under available commodity codes by USDA [21] and Eurostat [13], i.e. might not cover all imports.
[e] USDA [17].

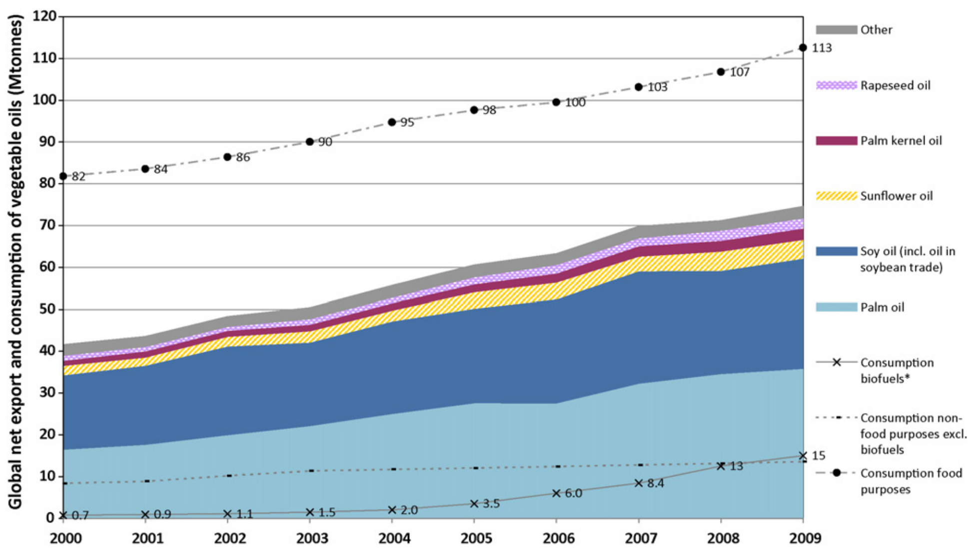

Fig. 4. World net vegetable oil export and consumption in Mtonnes (Data: [22]).

and Europe. International trade in rapeseed oil is dominated by Canadian exports to the US, the EU and China. European imports of rapeseed and rapeseed oil have however been dominated by Ukrainian exports in recent years [13].

Over the past ten years, the strongest relative increase in vegetable oil consumption can be attributed to biofuels while the largest total increase (and underlying trade flows) was caused by food and non-food consumption other than biofuels (see Fig. 4). In

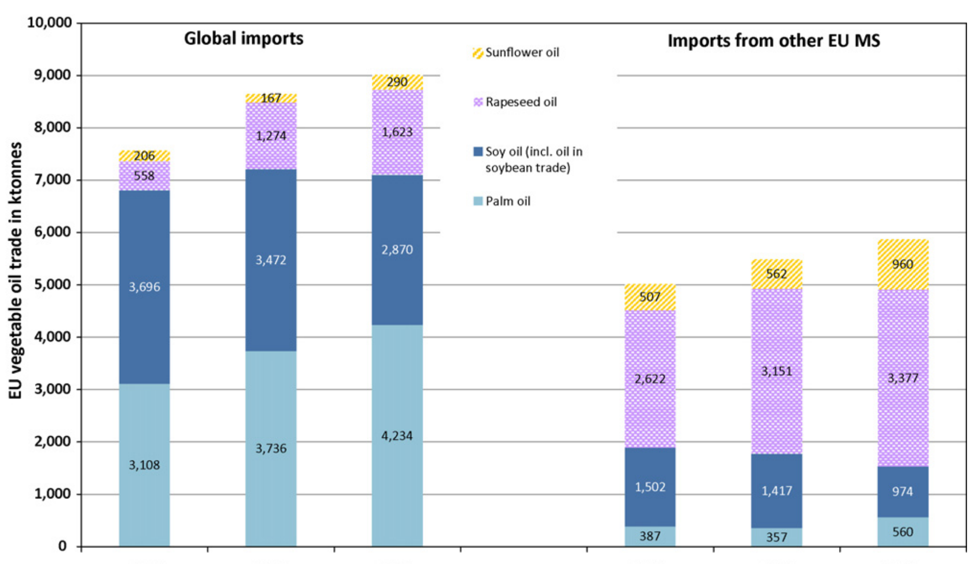

Fig. 5. Imports of vegetable oil into the EU of global and other EU MS origin 2007–2009 in ktonnes (Data: [13]).

the US, the main biodiesel feedstock is soybean oil. In the EU, it is rapeseed oil. However, with the introduction of biofuel mandates, the price competitiveness of palm and soy oil (including the fact that palm oil can be imported duty free into the EU) lead to a sharp increase in their proportionate share in EU biodiesel. Technical limits in the EU biodiesel standard EN 14214 however cap the possible share of palm oil in EU biodiesel. Trade in rapeseed oil is small on a global scale compared to palm and soybean oil; though its relevance for EU biodiesel remains high. This is also shown in Fig. 5 which illustrates its rising share in external imports and intra-European trade.

4.2. (Bio-)Ethanol

As Fig. 1 presents, world fuel ethanol production grew from 16 Gl (338.7 PJ) to 72.8 Gl (1540 PJ) over the last decade (see e.g. [79] for earlier years). More than 87% of the global fuel ethanol production has been concentrated in the US and Brazil. While Brazil has been the leading producer and consumer for decades, it was surpassed by US production in 2005 (see also [5]). Since 2008, the US covers more than 50% and Brazil slightly more than 30% of the world fuel ethanol production; a situation that was reversed only ten years ago. The EU share in the global fuel ethanol production matrix increased since the introduction of EU biofuel policies in 2003 but only reached 5% of global production by 2009.

Shortly after 2000, the US supply and demand of biofuels slowly increased due to rising petrol prices, an increasing awareness of US crude oil import dependence, and potential environmental benefits through biofuels. Despite subsidies for ethanol production, the main barriers to earlier development of biofuels in the US largely result from a lack of priority of these three factors as well as the geographic distance between the inland production (corn and soy are mainly grown in the Midwest section of the US) and the large consumption areas along the coasts [58,62]. Key market drivers for US biofuel – especially corn based ethanol—production in following years (see Figs. 1, 3 and 6) included the introduction of the Volumetric Excise Tax Credits (VETC) in 2004, the passing of the US Renewable Fuels Standards (RFS1) in 2005, and the full replacement of MTBE with ethanol in more than 25 US States by 2006. Additional incentives were provided through agricultural subsidies, corn in particular.

The RFS1 target for 2012 (7.5 billion gallons of biofuels) was met in 2008—almost exclusively by corn starch ethanol (see e.g. [54,79]). The current RFS2 includes a 15 billion gallon target for this type of ethanol. By 2009, the US produced already 10.75 billion gallons (~861 PJ) worth of fuel ethanol. Estimates for 2010 are between 12 and 12.6 billion gallons or 961 PJ [23] to 1008 PJ (own calculations based on [12,21]) respectively. By April 2010, 201 ethanol facilities were in operation with a technical capacity of 13.5 billion gallons [23]. Several facilities are currently under construction and it is assumed that the US will soon have the installed capacity to produce its RFS2 ethanol target of 15 billion gallons. The domestic market in the US is increasing saturated (based on blending limitations). This, in combination with comparatively low production costs, has created opportunities for increased international sales and resulted in a sharp increase in US (fuel) ethanol exports—also to the EU [13,38,46]. By the end of 2010, the US is expected to have become a net exporter of fuel ethanol.

While the US biodiesel trade balance revealed strong fluctuations in production, consumption, imports and exports over the last years (see Fig. 3), the US trade balance for fuel ethanol shows a continuous growth in both production and consumption (see Fig. 6). Fuel ethanol net imports were relatively high in 2006 since several states' voluntary phase-outs of MTBE went into force that year (see e.g. [87]). Since then, domestic production has kept up with the increasing demand and has led to an overall decline in net imports. According to Hess et al. [58], US fuel ethanol exports are marginal, i.e. net imports could be taken as total imports. For the years since 2008, USDA [21] has published fuel ethanol import data.[18] However, this data differs to that published by the EIA [12] in 2008 (24.3 PJ instead of 42 PJ).

US ethanol imports originate mainly in Brazil and the Caribbean, and to a lesser extent also Canada (see Table 5). Ethanol imports from Saudi Arabia were replaced by Brazilian imports by 2004 largely because Saudi Arabian ethanol was of synthetic origin and did not qualify under the VETC. The introduction of the VETC also meant an increase in US market value for imported ethanol. Hence it became lucrative to import Brazilian ethanol despite US import tariffs (see Table 13, Appendix). In recent years, more fuel ethanol has been transferred to the US via the CBI and CAFTA states than Brazil (see Table 5) (see Yacobucci [87] for a discussion on this issue).

US ethanol exports (all purposes) are mainly destined for Canada and the EU (see [21]). Previous exports to Mexico have been diverted towards the EU since 2004, i.e. one year after the introduction of a EU-wide biofuel quota.

While the ethanol production in the US was essentially sparked by domestic policies, Brazil's ethanol production increased continuously over the past decade largely due to the high demand for sugar on the local and international market, the continuous improvements in productivity and the growing international demand for fuel ethanol [5]. Currently, Brazil is the world's leading exporter of fuel ethanol. Its exports have risen continuously and are primarily destined for the EU and the US (to a large share via the Caribbean); to a lesser extent also to Japan and South Korea (see Fig. 7). Exports reached an all-time high in 2008, which was primarily supported by high international crude oil prices that made Brazilian ethanol cost competitive in export markets despite EU and US tariffs (see Table 1) [42]. Trade volumes have also been affected by weather conditions, which influence harvests in exporting regions (e.g. reduction through adverse weather conditions in Brazil in 2009) as well as those in potential import destinations (e.g. floods in the US reduced corn harvests in 2008), and thus the global supply and price of alternative feedstock—grains in particular.

Since international grain prices were low in 2009, Brazilian ethanol imports to the EU and the US were less cost-competitive (under the given tariff levels) on these markets and export volumes shrunk (see Fig. 7). At the same time, a 'sugar gap' on the global market in 2009 lead to an increase of exports to other sugar producing nations such as India (see Fig. 7). According to the Brazilian Sugarcane Industry Association, the downward trend of exports to the US and the EU is bound to continue in 2010 [42].

Brazilian ethanol exporters have been known to use the Caribbean free trade agreements of the US to import their ethanol duty free. This triangular trade seems to be used particularly in years in which other market prices (primarily grain) influence the competitiveness of Brazilian fuel ethanol (see also Table 5).

The EU production of fuel ethanol rose from around 177 Ml (3.74 PJ) in 2000 to about 3.70 Gl (78.3 PJ) in 2009 (see Figs. 1 and 8). However, significant production increases can only be registered for the period after the introduction of the EU biofuel quota and tax exemption measures in 2003. The main production takes place in the former EU15 states (see [14]), and most capacity is currently being installed in France, Germany, Spain, the Benelux, and Poland [20]. A major limiting factor in EU ethanol production is feedstock costs [79]. Overall, capacity utilization has grown from 36% in 2003 to 63% in 2009; relatively low rates were observed for 2007 (45%) and 2008 (51%) (own calculations based on [30,33]). This was partly

[18] Under HS codes 2207.20.00.10 and 2207.10.60.10.

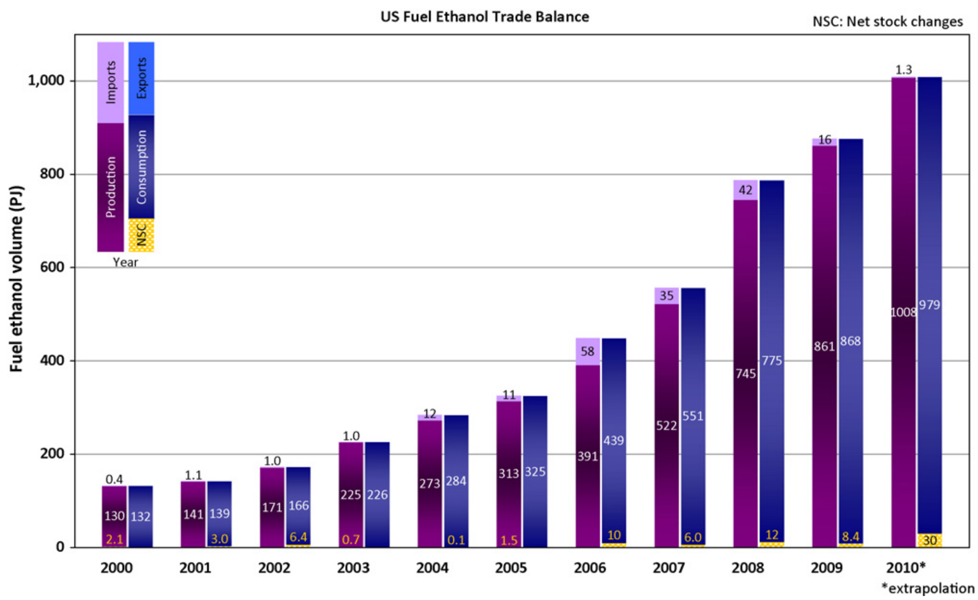

Fig. 6. US fuel ethanol trade balance 2000–2010 in PJ (Data: [12,21]).

Table 5
US (fuel) ethanol imports 2000–2009 in PJ (Data: [21,41]).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
EU27	0.3	0.3	0.8	1.0	0.8	0.7	0.8	0.5		
CBI + CAFTA	4.8	3.5	3.6	4.9	5.6	8.3	13.5	19.0	12.6[a]	14.2[a]
Brazil	0.8	0.3	0.6	1.0	9.0	5.8	36.3	18.0	11.5[a]	0.3[a]
Canada	0.8	1.0	0.9	0.7	0.9	1.0	1.7	1.8	0.1[a]	1.2[a]
Argentina	0.6	0.5	0.6	0.6	0.6	0.3	0.5	0.4		
Saudi Arabia	5.6	5.9	4.0	5.7	1.2					
Others	0.3	1.3	0.7	1.0	1.0	0.9	4.9	1.0		
Total	13.3	12.8	11.3	14.8	19.1	17.0	57.7	40.7	24.3[a]	15.7[a]
Brazil exports to US (all ethanol)	n/a	n/a	n/a	n/a	9.0	5.5	37.0	18.0	32.1	5.7
Brazil exports to CBI + CAFTA (all ethanol)	n/a	n/a	n/a	2.2	5.0	n/a	10.3	19.7	27.8	16.4

[a] Fuel ethanol only.

due to some plants not yet being fully operational but mainly due to high international grain prices and increasing amounts of competitively priced imports from Brazil [20] (see Figs. 8 and 7). A year later, in 2009, lower grain prices stimulated an increase in production (by 31%) and capacity utilization, and thus also a reduction of imports. The traditional EU ethanol feedstock is wheat and sugar beats with increasing shares of corn, rye, barley, and wine ethanol surpluses [20,79].

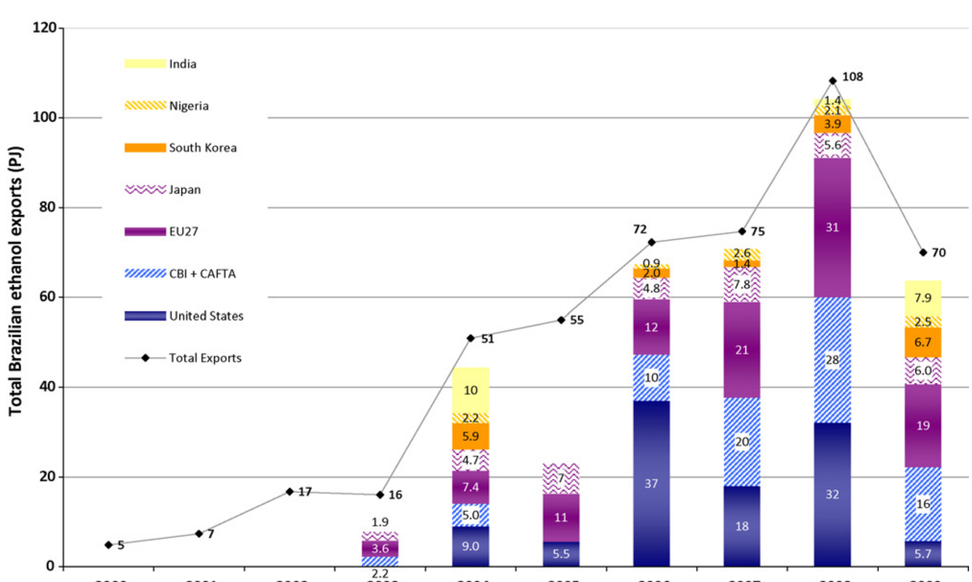

Fig. 7. Total Brazilian ethanol exports (all purposes) 2000–2009 in PJ (Data: [41,42,79,88]).

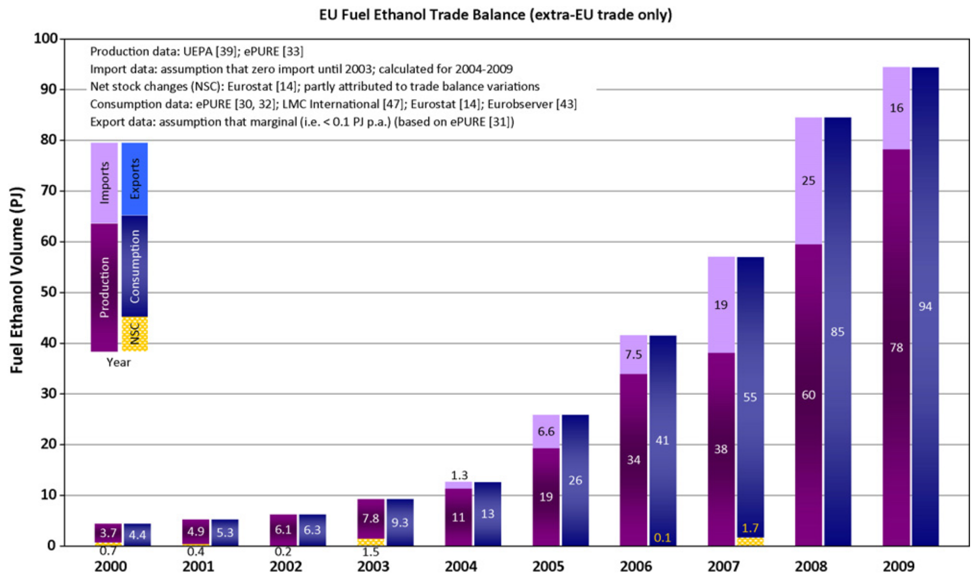

Fig. 8. EU fuel ethanol trade balance 2000–2009 in PJ (Data: [14,30–33,39,43,47]). *Note*: Eurostat [14] trade data includes intra-EU trade. Additional sources were used here to extract international trade only.

Table 6
EU fuel ethanol imports 2005–2009 in PJ (Data: [13]; own calculations).

	2005	2006	2007	2008	2009	Current tariff
Brazil	3.1	3.5	10.6	15.8	6.5	10.2–19.2 €/hl
Guatemala	0.6	0.4	0.8	0.7	1.6	0%
Pakistan	0.9	0.7	1.4	2.0	1.0	10.2–19.2 €/hl
Nicaragua	0.1	0.1	0.3	0.0	0.9	0%
Peru	0.2	0.2	0.6	1.0	0.9	0%
Bolivia	0.1	0.3	0.1	0.9	0.8	0%
Egypt	0.2	0.4	0.6	0.9	0.7	0%
Costa Rica, Jamaica, El Salvador	0.1	0.2	0.9	1.4	1.1	0%
Others	1.2	1.7	3.6	2.2	2.7	
Total	6.55	7.54	18.87	24.95	16.15	

EU ethanol production centers are also the most important consumers with Germany, France, Sweden, Spain and Poland leading the way since 2005 [14]. Germany, France and Sweden are currently the only MS that support the utilization of higher ethanol blends. It is expected that production will grow strongly in Benelux harbors in coming years which also serve as strategic crude oil locations, i.e. for biofuels blending and further distribution [20]. Rotterdam harbor already serves as the main entry gate of international ethanol imports to the EU (destined mainly for UK, Sweden, and Benelux) [20]. While the UK, the Netherlands, and Sweden have been importing ethanol for several years, imports to other MS including France and Poland have jumped from almost zero in 2007 to around 90 Ml (1.9 PJ) each in 2008 [14]. As for the US market, this increase is exclusively attributed to high grain and crude oil prices that made international ethanol imports (in particular from Brazil) cost competitive with EU production despite import tariffs.

In most EU MS—apart from the UK and the Netherlands, only blends of undenatured ethanol qualify for national biofuel quotas [16,20].[19] This shields local production against cheap imports (mainly from Brazil) as tariffs for undenatured ethanol are almost twice those of denatured ethanol. These tariffs are also comparatively higher than US ethanol import taxes (see Table 13, Appendix A). Since 2002, the vast majority (80–95%) of EU ethanol imports have been undenatured [13].

[19] See e.g. Germany as in §37b Bundesimmissionsschutzgesetz [Federal Immission Protection Law].

Unsurprisingly, there have been efforts in the past to circumvent EU ethanol tariffs. The most prominent was the so-called 'Swedish loophole'; an effect triggered by the absence of specific fuel ethanol custom codifications as ethanol could be imported under alternative tariff lines (with lower duties). By mixing ethanol with 12.5–20% gasoline just prior to customs declaration, ethanol for fuel blending was imported into Sweden under the 'other chemicals' tariff line (CN 3824) thus reducing the tariff to 6.5% rather than 63% for undenatured or 39% for denatured ethanol [50]. In addition, ethanol imported to Sweden this way was eligible for tax exemptions as a biofuel until 2006. Ultimately, legislative changes were made in 2007 that allowed only ethanol entering under the higher duty to benefit from the tax break. Nevertheless, the loophole has still been used when cheap ethanol imports (e.g. from Brazil) and the lower duty (for 'other chemicals') compensated the absence of the tax exemption. According to the USDA [20], the quota was reopened in April 2010 with an import license for a period of one year. Concerns were also recently raised at a meeting of the UK Renewable Transport Fuels Group on August 5th 2010 about similar practice regarding import into the UK [89].

The portfolio of EU fuel ethanol imports is assumed to be the same for all ethanol since imports are pooled and no custom declarations are given per final end-use. Total EU ethanol imports, as listed in the Eurostat [13] database, have been larger in any given year than fuel ethanol imports only (as derived via the trade balance, see Fig. 8). In addition, there remains to be unclassified trade under the customs category of 'other chemicals' [31]. Thus, trade data was derived by combining total fuel ethanol imports (see

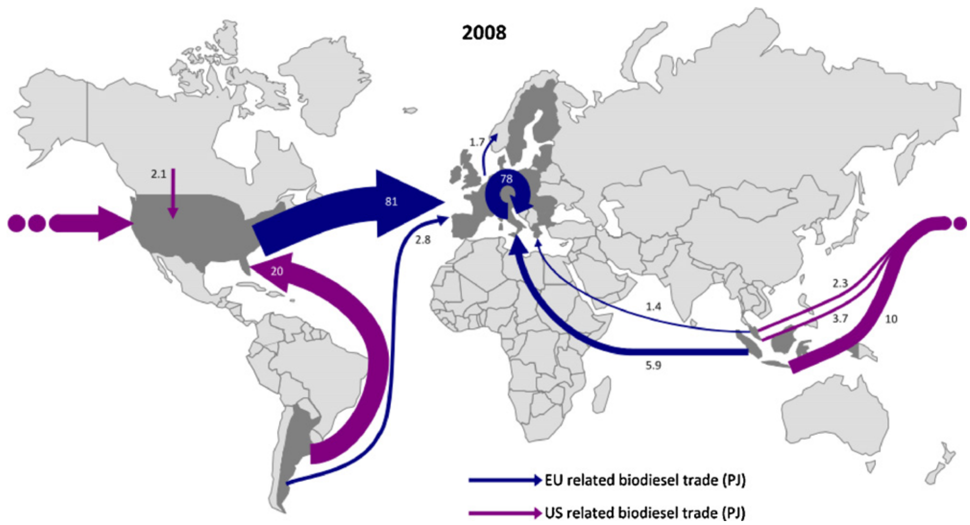

Fig. 9. Global biodiesel trade streams of minimum 1 PJ in 2008.

Fig. 8) with ethanol import volumes by country (as in Ref. [13]). The result of this calculation is shown in Table 6. It indicates that Brazil has been the main importer of (fuel) ethanol to the EU while other nations subject to tariff preferences, in particular from Central and South America, have increased their shares in recent years (see also drop in Brazilian ethanol exports to EU from 2008 to 2009 in Fig. 7). According to Eurostat [13], imports of US corn based ethanol increased sharply during the first four months of 2010. They are however likely to decline again by 2013 under the sustainability requirements of the EU Renewable Energy Directive [55].

5. Global liquid biofuel trade volumes

There still is a lack of scientific analysis on the net international trade volumes of liquid biofuels. First rough estimates were given by Heinimö and Junginger [5]. The analysis undertaken here compares a wider range of sources and shows different (lower) trade volumes than Heinimö and Junginger [5]. The methodology builds on the central observation (of liquid biofuel trade developments in the past decade) that the most lucrative markets – from a producer's and trader's perspective – are the EU and the US due to the underlying support policies and thus market value for liquid biofuels. Furthermore, findings on typical trade routes from Section 4 (see Figs. 9–12) are used to establish assumptions and to avoid double-counting.

5.1. Biodiesel

The major biodiesel trade flows and volumes of the past two years (as discussed in Section 4) are presented in schematic form in Figs. 9 and 10. The estimation of the global net biodiesel trade is based on the following assumptions: Brazil remains to be a closed market regarding biodiesel trade. Exports from Argentina, Malaysia, and Indonesia are exclusively dedicated to markets in the EU and the US (for above reasons). None of the countries re-export biodiesel, but rather derive all exports through domestic production. Due to the US blending practice under the VETC, all US imports are assumed to be re-exported to the EU. The domestic production share in US exports is thus net exports (total exports minus imports). Since the EU has become the key target market for biodiesel, total world trade also includes EU imports in addition to those of the countries mentioned. Prior to 2007, EU exports are accounted for as well. Afterwards they are excluded to avoid potential double-counting (i.e. re-imports via the US). The calcu-

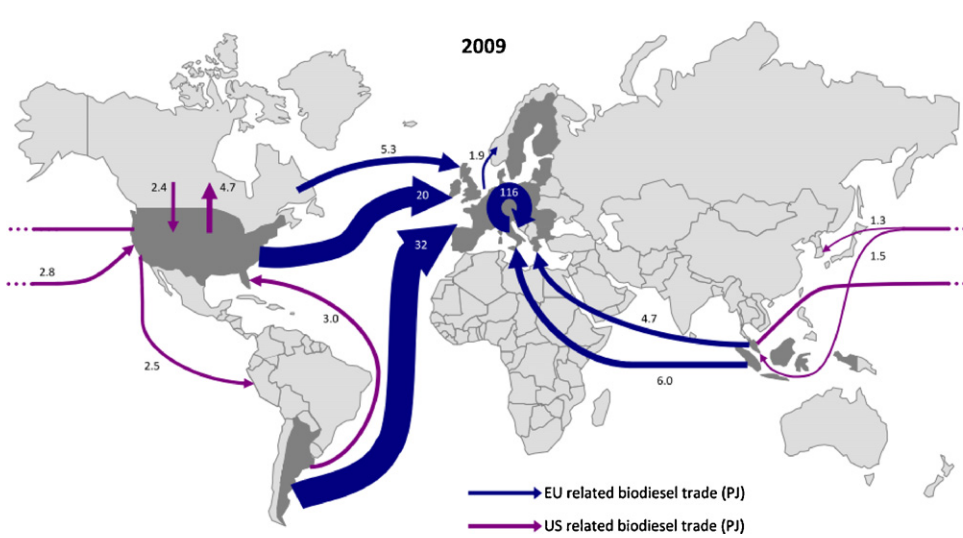

Fig. 10. Global biodiesel trade streams of minimum 1 PJ in 2009.

Table 7
Total net biodiesel trade 2000–2009 (in PJ).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AR, MY, ID exports							2.8	16.7	43.4	59.1
US net exports (US produced)				0.1	0.1			16.5	45.5	23.7
EU imports excl. US, AR, MY, ID						1.1				
EU exports prior to 2007						0.8	1.0			
Total world biodiesel trade	0.0	0.0	0.0	0.1	0.1	1.9	3.8	33.2	88.9	82.7
Share in global biodiesel production	0%	0%	0%	0%	0%	1%	2%	10%	18%	14%

lation shows an increase of total biodiesel net trade of more than 80 PJ in ten years (see Table 7).

5.2. (Bio-)Ethanol

Global ethanol trade streams above 1 PJ for 2008 and 2009, as discussed in Section 4, are presented in Figs. 11 and 12. To assess net trade developments, the following assumptions are made: first, Brazil, the US and the EU have been the exclusive fuel ethanol consumers in the last ten years. Since 2006, fuel ethanol has also been consumed outside these countries in small quantities. Secondly, the US fuel ethanol exports have been marginal before 2009 and are thus neglected. All Brazilian fuel ethanol shipped to the Caribbean is destined for markets in the US (via the CBI and CAFTA). Third, while more and more countries emerge as potential fuel ethanol producers and exporters, Brazil has been the exclusive fuel ethanol exporter for the past decade. Finally, an increasing amount of re-exporting is taking place in the EU.

A first benchmark is thus derived by adding the net fuel ethanol imports of the EU and the US plus Brazilian fuel ethanol exports to destinations other than these regions (including CBI and CAFTA). Based on historic Brazilian ethanol export numbers (all purposes; see Fig. 7) such exports can be assumed to make up about 20% of all Brazilian ethanol exports until 2005 and about 50% in the following years until 2009. A second benchmark is calculated by assuming that a maximum of 50% of all Brazilian ethanol exports to the US, EU and the Caribbean were destined for fuel usage until 2004 while this share increases to about 90% in the years 2005–2009. This higher share is in-line with industry data from FO Licht [46]. The lower share in earlier years is based on lower total EU and US import numbers and a comparatively high domestic production that covered most the domestic fuel ethanol demand. To complete the second benchmark, this volume is added to US and EU net imports, which originate neither in the Caribbean nor in Brazil. The range of these two benchmarks is presented in Table 8.

Fuel ethanol trade volumes have – just as for biodiesel – risen over the past decade. While more fuel ethanol than biodiesel has been traded for most years, total biodiesel trade is far larger in 2009. In addition, the relative share of trade compared to world production is significantly larger for biodiesel in the years after 2007. These trade volumes are certainly connected to blending and trade practices in connection to the US VETC for biodiesel.

6. Results: policies and market factors

In economic terms, trade contributes to a more cost efficient distribution of goods across global markets. At the same time, trade can appear threatening to domestic industry. In the past decade, biofuels were promoted by governments worldwide for a number of reasons including the enhancement of the security of energy supply or reducing GHG-emissions, but also job creation and revenue generation for local industry (e.g. introduction of VETC as part of the US Job Creation Act [64] in 2004). However, as this analysis has shown, EU and US biofuel policies, originally strictly aimed at promoting domestic industry, had significant impacts on world biofuel production and trade patterns. Table 9 presents a summary of the biofuel related policy measures of the EU and the US. It shows that the initial goal and the actual outcome of the policies do not always match, and provides reasons why this is the case.

A prime cause for the unintended impact on international trade seems to lie in the mere focus on steering domestic production and consumption while neglecting international trade aspects (market factors) in biofuel policy making. A striking example is the design of the US VETC. The main aim of US biofuel policies was and still is the promotion of the national fuel ethanol industry. To prevent imports from being blended under the tax credit, i.e. to favor domestic production, an import tax was implemented for fuel ethanol. However, such a tax has not yet been leveled on biodiesel imports. The effect of which could be observed in the 'B99' or 'splash-and-dash practice' as described in Section 4.1.

Examples also exist on the EU-level where the introduction of blending mandates and the phase-out of tax exemptions across several EU MS automatically led to a higher share of imports as blenders were interested in keeping their biofuel costs to a minimum and ultimately preferred cheaper imports (of palm and soy oil derived biodiesel) over domestically produced (rapeseed) biodiesel. Another EU example is the introduction of anti-dumping and countervailing measures against US produced biodiesel that neglect the option of triangular trade or the general possibility for traders to down-blend and import biodiesel below the customs mark of B20 concentrations.

Before deriving lessons on how such aspects could be reflected in policy making, one has to first understand how policy factors and market forces interact to influence international biofuel trade. Clearly, biofuel support policies in the EU and the US have prompted an increased international production and trade in liquid biofuels across the past decade. While these policies have acted as the trigger, it is important to stress that actual trade flows evolved due to interconnected and additional market/economic factors. It was also market factors, i.e. price differences on the EU and US markets (connected to the underlying support policies) which directed international biofuel trade flows towards one region or the other.

As a general rule, it appears, support policies (artificially) increase the domestic market value for biofuels. Wherever these policies/prices are not accompanied by trade measures restricting trade volumes or imposing import duties, international trade develops. However, even under the presence of trade measures, trade is economically viable for export regions with large resource potential and relatively low production costs compared to the US and the EU (i.e. Argentina, Malaysia, and Indonesia for biodiesel, Brazil and increasingly also other Central and South American countries for sugar cane based fuel ethanol). Thus, international trade in liquid biofuels is both demand and supply driven. Production costs and trading options are also influenced by additional short- and long-term market factors such as varying international feedstock and crude oil prices. A complete overview of influencing factors is given in Table 10.

Hence, to steer international biofuel trade, policy makers would need to influence the economics of trade. Since they have limited to

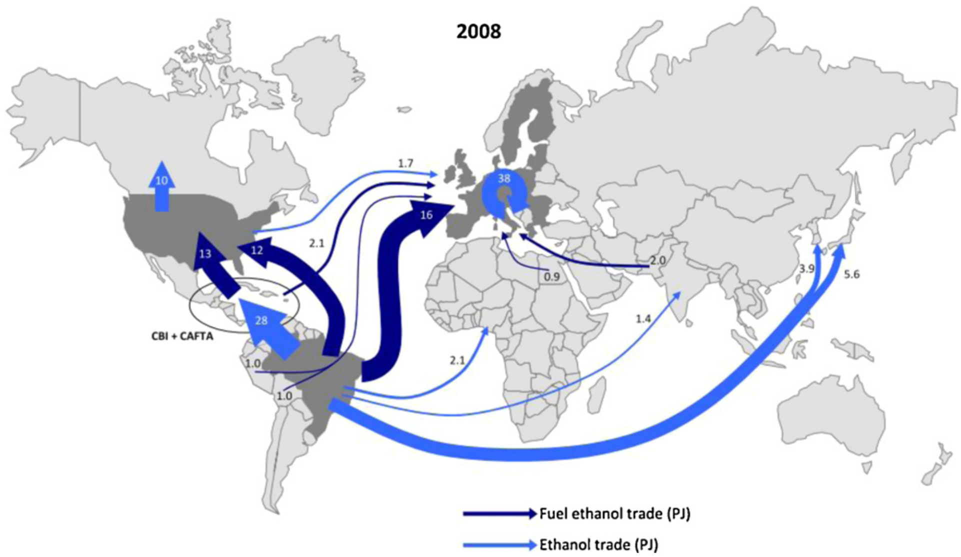

Fig. 11. Global (fuel) ethanol trade streams of minimum 1 PJ in 2008.

Table 8
Data ranges for world net fuel ethanol trade 2000–2009 (in PJ).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
EU net fuel ethanol imports					1.3	6.6	7.5	18.9	24.9	16.1
US net fuel ethanol imports	0.4	1.1	1.0	1.0	11.9	10.9	58.5	35.2	42.4	15.5
Brazilian fuel ethanol exports (excl. CBI, CAFTA, US, EU)					5.9	7.7	6.2	7.8	8.6	14.6
First benchmark	0.4	1.1	1.0	1.0	19.1	25.2	72.3	61.9	75.9	46.3
Brazilian exports to EU, US, CBI, CAFTA				2.9	10.7	14.7	53.6	53.1	82.0	36.6
US imports excl. Brazil, CBI, CAFTA	0.4	1.1	1.0			5.4	11.3			
EU imports excl. Brazil										
Second benchmark	0.4	1.1	1.0	2.9	10.7	20.0	64.9	53.1	82.0	36.6
World net fuel ethanol trade	<1	∼1	∼1	1–3	11–19	20-26	65–71	53–62	76–82	37–47
Share of global fuel ethanol production	0%	0%	0%	0%	2–3%	3–4%	8–9%	5–6%	5–6%	2–3%

no influence on many of the market factors, their remaining option is to carefully design policies and trade regimes taking international biofuel policies and trade regimes of other nations into account (see Kaditi [90] for a broader discussion).

7. Reflections and conclusions

World biofuel production has grown exponentially across the last decade and with it global trade in biofuels and their feed-

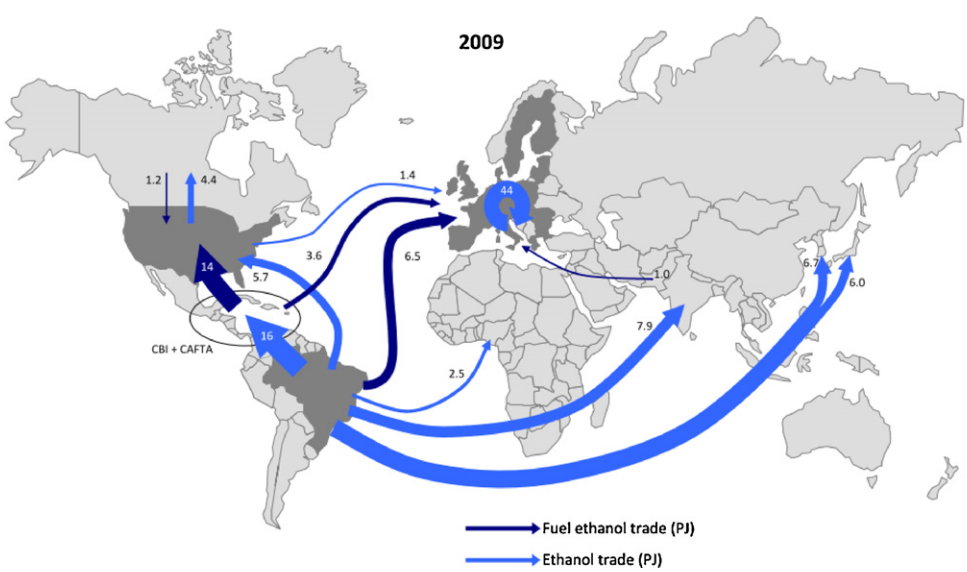

Fig. 12. Global (fuel) ethanol trade streams of minimum 1 PJ in 2009.

Table 9
EU and US biofuel policies, their purposes, outcome, and underlying reasons.

Policy	Initial purpose	Outcome	Reason
EU Biofuels Directive (2003/30/EC)	Minimum EU market share for biofuels	Strong production increase in biofuel production, esp. biodiesel; 2005 and 2010 targets were not reached	Diesel dominates the EU fuel matrix
EU Energy Tax Directive (2003/96/EC)	Allowance for MS to provide financial incentives to biofuel production to compensate for additional production costs	14 MS introduced mandates in addition to (initially heavy) tax incentives to cut public spending over the years	Long-term policy target provided investment basis but implementation in MS varied, i.e. some MS exceeded the targets, others underperformed; in some MS penalty payments for non-compliance were less costly than actual biofuel blending
EU Renewable Energy Directive (2009/28/EC); EU Fuel Quality Directive (2009/30/EC)	Minimum market share and GHG emission savings target for biofuels fulfilling specific sustainability requirements	Expectation that domestic production will be strengthened and imports will shift to GHG-efficient biofuels	Due to existing industry, environmental, and social standards, proof of compliance is somewhat easier within the EU; GHG-performance will become a benchmark in many MS hence increase the demand for GHG-efficient biofuels (incl. imports)
EU trade regime for biodiesel	Protect domestic production from cheap imports in particular US subsidized biodiesel	Import shares have increased over the years with a peak of US exports in 2008; since the introduction of EU countermeasures in 2009 direct US biodiesel imports are marginal (or down-blended in EU ports just before customs) and were replaced by imports from Argentina, Indonesia, Malaysia, and Canada	Key importing nations have lower production costs and also mostly enjoy tariff preferences; EU tariffs are on ad valorem basis, i.e. favor cheap(er) imports; under EU countermeasures, US produced biodiesel is subject to triangular trade and down-blending as EU tariffs only cover B20 blends or higher
EU trade regime for (fuel) ethanol	Protect domestic production from cheap imports	EU fuel ethanol imports vary with international grain and crude oil prices but did not reach the volumes of biodiesel imports; Brazil remains the key sourcing region while an increasing share of EU imports originate from countries enjoying tariff preferences (including Brazilian re-exports)	High production efficiency and climatic conditions make Brazilian fuel ethanol very cost efficient esp. under high international grain and crude oil prices; EU tariffs are leveled per liter not ad valorem (to counteract cheap and esp. Brazilian imports) increasing incentives for triangular trade
EU trade regime for biodiesel feedstock	Protect domestic vegetable oil production, i.e. duties on rapeseed, sunflower, and soybean oil but not on respective feedstock or palm oil	Heavy palm oil but limited other vegetable oil imports; increasing imports of oilseeds for crushing	Feedstock volume and price is a key factor for EU biodiesel production; palm oil enters the EU duty free; EU harbors have large crushing capacities and biofuel mandates allow any biodiesel type (as long as technical and FQD standards are kept)
2005 US Renewable Fuel Standard (RFS1)	Production of 7.5 billion gallons of biofuels by 2012	Heavy increase in corn derived ethanol Production target was exceeded by 2008	Petrol dominates the US fuel matrix; simultaneous ban of MTBE (as a petrol additive) and replacement by bioethanol in more than 25 US States lead to production increase beyond target
2007 US Renewable Fuel Standard (RFS2)	Production of 36 billion gallons of biofuels by 2022	Further increase in corn derived ethanol and Brazilian ethanol imports; slow growth in biodiesel production	15 billion gallons corn derived ethanol possible, plus corn subsidies and farming sector orientation; 20 billion gallons must be advanced biofuels, i.e. sugarcane (primarily Brazilian origin) and lignocellulosic ethanol (domestic R&D); biodiesel expected to only have a 1 billion gallon market share
US Volumetric Excise Tax Credit and trade regime for fuel ethanol	Incentivize domestic fuel ethanol production by blending tax credit Prevent abuse of tax credit by installing import tax (by volume)	Strong production and blending increase of (US) corn derived ethanol; increase in ethanol imports from Brazil and the Caribbean over the years	Financial incentive in connection with MTBE ban and long-term policy targets (RFS); import tax on ethanol prevents all but the most cost efficient and/or duty free ethanol from entering the US
US Volumetric Excise Tax Credit and trade regime for biodiesel	Incentivize domestic biodiesel production by blending tax credit	Production increased slowly due to limited domestic demand; when producers and traders got aware of the margins of re-export to the EU, the splash-and-dash practice started; during this phase US imports from Argentina and Indonesia (exempted from tariff preferences) increased heavily	VETC blending incentive is not connected to an import tax; import duties apply on ad valorem basis thus favoring cheap(er) imports; due to additional support measures after import market value for biodiesel is higher in the EU than the US

Table 10
Influencing factors: policies and market-related aspects.

	Stimulating the domestic biofuel market	Increasing international biofuel trade
Policy		
Production related measures/policies	Investment support for local production facilities, RD&D, infrastructure projects, etc. Agricultural subsidies (e.g. EU CAP, US corn) Tax incentives in combination with import duties (e.g. VETC for fuel ethanol in US) Production mandates	Tax incentives without import duties (e.g. VETC for biodiesel in US) Differentiated export taxes (e.g. Argentina: reduced taxes for non-food products)
Consumption related measures/policies	Consumption mandates or incentives targeting domestically produced biofuels in combination with trade measures limiting biofuel imports (e.g. eligibility criteria under mandates such as undenatured ethanol in some EU MS)	Consumption mandates or incentives that do not discriminate the type or origin of the biofuel (e.g. blending mandates in the EU leading to a diversification of biodiesel feedstock)
Trade related measures/policies	Import duties/taxes Technical standards	Tariff preferences Varying tariff/duty levels stimulating alternative or triangular trade
	Sustainability criteria (if fulfilled by domestic production and sufficient, cost and GHG efficient biomass available; or criteria hard to fulfill by international imports)	Sustainability criteria (if not sufficient, cost or GHG efficient biomass available in export destination and criteria fulfillment in exporting country is possible)
Market		
(Long-term) Market factors	Strong agricultural sector: existing infrastructure for feedstock production and processing including (strong) market players with respective know-how, networks, and associations (driving political support)	Agricultural export orientation
	Availability of cost efficient domestic feedstock Imbalanced transport fuel matrix guarantees a long-term market for investors and traders of respective biofuel substitute(s)	Preferential climatic conditions (i.e. biomass potential) General lack of feedstock production potential in export destination (long-term) or adverse climatic conditions affecting volumes and/or prices of domestic feedstock (short-term)
Short-term market factors in regards to the EU and US	Decrease in crude oil prices significantly reduces production costs of grain and oilseed derived biofuels	Increase in crude oil price enhances the cost competitiveness of efficiently produced biofuels (esp. sugarcane derived fuel ethanol from Brazil)

CAP: Common Agricultural Policy (EU); MS: Member State (EU); RD&D: research, development and demonstration; VETC: volumetric excise tax credit (US).

stock. Within these ten years, biodiesel production rose from below 30 PJ (0.8 Mtonnes) in 2000 up to 572 PJ (15.2 Mtonnes) in 2009. World fuel ethanol production climbed from 340 PJ (16 Gl) in 2000 up to over 1540 PJ (73 Gl) in 2009. Clear distinctions between biodiesel and fuel ethanol markets lie in the different geographic developments; primarily connected to the different transport fuel demands, biofuel and agricultural policies, and interests of the respective market players. Global biodiesel production has been dominated by the EU which still covers around 60% of the production in 2009. Historically, more than 87% of the global fuel ethanol production has been concentrated in the US and Brazil. Since 2008, the US has covered more than 50% and Brazil slightly more than 30% of the world fuel ethanol production; a situation that was reversed only ten years ago.

While practically no biofuels were traded ten years ago, world net biofuel trade reached 120–130 PJ in 2009. Trade streams are directed towards the most lucrative markets. For biodiesel this has evidently been the EU whose imports reached 92 PJ in 2008 and 70 PJ in 2009. Prime underlying cause for this surge was the so-called splash-and-dash practice which made it possible to import biodiesel into the EU which had previously been granted tax exemptions in the US. At least 81 PJ of EU imports came from/via the US in 2008. 40 PJ of these exports had previously been US imports; primarily from Argentina, Indonesia, and Malaysia—all of which are expected to remain leading biodiesel exporters in the future. The US market for biodiesel is believed to remain limited under the RFS2; thus local producers and traders will continue to focus on export options under current US biofuel and trade policies. Brazil is also a large producer of biodiesel, 53 PJ in 2009, but remains to be a closed market due to different technical standards and remote locations of its biodiesel production plants.

Regarding fuel ethanol, both the US and the EU have been attractive markets for competitively priced international exports. While a lack of end-use specification leaves a level of uncertainty on the exact trade volumes, it is clear that the vast majority of fuel ethanol trade has originated in Brazil. Ethanol production in the US and EU is largely based on corn and wheat. Brazilian sugarcane based ethanol has proven to be cost competitive in either market despite the respective trade regimes. In addition, large quantities of Brazilian ethanol were re-directed via Caribbean states to reduce/set-off tariff duties in the US and the EU. In the long run, both markets are expected to remain attractive for ethanol exporters. On short-term however, increasing domestic market saturation (based on blending limitations) and high production levels have caused the US to become a net exporter by 2010; thus directing the focus of international trade to the EU.

The underlying policies influencing and shaping these international trade streams were originally aimed at merely increasing national production and consumption; under the broader policy goals of enhancing the security of energy supply, reducing GHG emissions, diversifying the fuel matrix, and/or providing jobs and revenues for local industry, among others. Since support policies (artificially) increased the domestic market value for biofuels, trade patterns emerged in connection to the respective support levels and evolved in accordance with the respective trade regimes. It is found that import duties were key influencing factors on trade volumes, while trade routes were mainly shaped by tariff preferences.

Due to the nature of the underlying policy goals of biofuel support schemes, trade regimes (i.e. the definition of import duties and tariff preferences) were generally designed and adapted unilaterally, in-line with national interests. Given the pace of the international biofuel market and trade development, such 'quick fixes' seemed justified but did not make the international biofuel market less risky for investors or more sustainable or efficient from a policy perspective. What's more, the country's individual agendas have caused several trade disputes. These include EU duties on US biodiesel but also WTO complaints of exporting nations regarding domestic subsidies in their envisaged export market (see e.g. [54]).

Table 11
World biodiesel production 2000–2009 as in literature and own calculations (*italic*) (in PJ).

	Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	REN21 [25]						8.3	28.2		66.3	69.7
	EIA [12]		1.1	1.3	1.8	3.5	11.4	31.4	61.5	85.1	64.2
	IEA [24]	0.2	0.6	1.9	2.5	3.1	9.4				
	USDA [23]										69.1
	AREC [26]									87.6	
Brazil	REN21 [25]							2.3		39.8	53.1
	ANP [11]		0.0	0.0	0.0	0.0	0.0	2.3	13.4	38.7	53.3
	USDA [15]		0.0	0.0	0.0	0.0	0.0	2.3	13.4	38.7	50.9
EU27	REN21 [25]						119.4	149.3		265.4	295.2
	EBB [29]			40.1	54.0	72.9	120.0	184.3	215.3	292.2	340.9
	IEA [24][a]	27.7	33.7	39.7	56.0	72.0	122.4				
	USDA [20]							177.8	226.2	292.2	318.8
	Eurostat [14]						116.6	199.8	257.3	298.0	
Argentina	REN21 [25]									39.8	46.4
	FO Licht [45]							1.1	9.4	30.1	49.0
	AREC [26]									36.2	
	USDA [19]							0.7	6.8	28.5	44.4
Thailand	REN21 [25]									13.3	19.9
China	REN21 [25]							2.3	*2.8*	3.3	13.3
Colombia	REN21 [25]							2.0	*4.3*	6.6	6.6
Malaysia	USDA [18]						6.3	12.2	15.1	15.8	20.3
	FO Licht [45]							1.9	3.8	7.2	9.0
Indonesia	Dillon et al. [71]									27.3	
	FO Licht [45]							1.9	9.2	8.7	13.9
	USDA [17]						0.3	2.6	3.8	3.4	3.0
Others[b]	Sum[c]						*0.3*	*8.1*	*20.1*	*39.0*	*62.8*
	Calculated upper value[d]						*13.6*	*49.4*	*42.1*	*143.7*	*155.7*
	Total emerging markets[e]	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.3*	*8.9*	*22.1*	*42.9*	*69.1*
WORLD	REN21 [25]						129.4	199.0		398.0	563.9
	FO Licht [44]	30.1	35.8	43.3	60.3	77.2	128.1	226.1	331.6	489.9	
	LMC [48]						120.6	229.9	339.1	542.6	610.4
	IEA [24]	28.3	34.6	42.3	60.1	77.0	138.6				
	Total[f]	*27.9*	*34.8*	*41.4*	*55.8*	*76.4*	*131.7*	*227.5*	*319.1*	*495.2*	*571.9*
	Minimum[g]	*27.9*	*34.3*	*41.0*	*55.8*	*75.1*	*125.3*	*189.3*	*319.1*	*441.9*	*523.8*
	Maximum[g]	*27.9*	*34.8*	*42.1*	*58.5*	*76.4*	*134.2*	*243.6*	*363.8*	*508.1*	*581.9*

[a] Original data source: European Biodiesel Board (EBB).
[b] Category covers emerging biodiesel producing nations apart from US, EU, Brazil, Argentina.
[c] Sum of grey boxes for Thailand, China, Colombia, Malaysia, and Indonesia only.
[d] Maximum level of production in emerging markets; calculated as the maximum world production minus minimum individual country data for US, EU, Brazil, Argentina; the actual calculated value for 2004 is zero whereas earlier years showed values between 0 and 1 PJ, those however were neglected as they are attributed to data variations for total world production and no biodiesel production outside the US and the EU is known for this period.
[e] Reflects the sum of production in Thailand, China, Colombia, Malaysia, and Indonesia plus a 10% uncertainty factor.
[f] Sum of all selected data as boxed grey.
[g] Sum of all minimum/maximum annual data from US, EU, Brazil, Argentina plus data 'Total emerging markets'.

To avoid such disputes and to reduce market inefficiencies and uncertainties, we deem it important that governments explicitly consider international trade implications of national trade policies. On international level, the WTO could contribute to the establishment of a level playing field by framing rules for national biofuel support measures (esp. subsidies), trade regimes (esp. import tariffs), and additional regulations or standards (esp. sustainability criteria) (see also [90,91]).

In order to reflect international trade implications in national trade policies, we believe, market transparency and understanding need to be improved. The WTO, again, could take on a key role by initializing international standardized custom clarifications, i.e. establishing a harmonized commodity description and coding system for biofuels including lower blends and differentiated by end-use. At present, heterogeneous international codes, a lack of end-use differentiation and data collection for lower blends reduce accuracy in trade estimations and leave options for non-classified trade (e.g. under the category 'Other chemicals' or by down-blending imports before customs declaration). To enhance the transparency of global biofuel trade patterns, it is in the interest of governments to engage in such a process of internationally harmonized biofuel coding, and to ultimately collect and publish data in an internationally comprehensive and homogeneous way. Building on such market data, additional scientific research is required to provide further insights into the underlying, complex and interwoven links in the rapidly developing market of international biofuel trade. This is particularly the case for evaluating how individual influencing factors on trade interrelate; a crucial component in mapping future trade streams under different policy and in particular trade regime scenarios. To provide such analysis, advancements in market forecasting (through modeling) are deemed to be necessary as well.

Appendix A. Appendix

A.1. Background on global biofuel production data

As outlined in the methodology section, world biodiesel production data was gathered and compared between various sources. The selected data as presented in Fig. 1 is boxed grey in Table 11. National ministries and data services appear to generally draw a solid picture and are available for several consecutive years as com-

Table 12
World (fuel) ethanol production 2000–2009 as in literature and own calculations (*italic*) (in PJ).

	Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	RFA [37]					283.0	341.4	422.5	520.3	720.5	814.3
	FO Licht [45]							388.7	519.2	739.5	858.6
	REN21 [25]					274.9	317.2	387.0		719.1	867.1
	LMC [47]				224.2	272.2	312.5	388.7	515.5	759.1	
	EIA [12]	129.9	141.3	171.3	224.5	272.5	312.6	391.0	522.1	745.2	861.3
	USDA [23]										860.5
Brazil	RFA [37]					319.3	338.4	359.6	401.8	518.1	526.6
	FO Licht [45]							353.2	423.0	511.8	505.9
	REN21 [25]					317.2	317.2	370.1		571.0	549.9
	LMC [47]				288.0	301.5	317.0	357.2	448.7	475.6	
	UNICA [41]	220.6	247.5	264.6	307.5	324.2	342.1	372.2	466.3	577.3	
	Calculated[a]	*203.0*	*227.7*	*243.4*							
EU27	RFA [37]					47.6	53.3	71.9	45.7	58.7	83.2
	FO Licht [45]							33.4	38.0	58.3	76.0
	REN21 [25]						19.0	12.7		59.2	76.1
	Eurostat [14]						22.9	35.0	46.7	63.3	
	USDA [20]							34.5	38.9	56.3	73.6
	LMC [47]				9.3	11.2	19.3	35.9	49.1	76.1	
	ePURE [33]					11.2	19.3	34.0	38.1	59.6	78.3
	UEPA [40]							31.8	36.7	47.7	77.7
	UEPA [39]	3.7	4.9	6.1	7.8	11.5	15.5	32.0	36.0	46.5	
Other	RFA [37]					212.3	239.6	226.0	81.1	90.4	139.8
	FO Licht [45]							54.6	67.7	87.5	99.7
	LMC [47]				9.2	16.7	35.6	57.0	65.4	94.2	
	Estimation[b]	*2.1*	*4.2*	*6.3*							
	Calculated upper value[c]	*19.8*	*24.0*	*28.3*	*10.6*	*277.4*	*327.7*	*417.4*	*469.3*	*525.8*	*502.3*
	Total emerging markets[d]	*2.1*	*4.2*	*6.3*	9.2	16.7	35.6	57.0	65.4	94.2	99.7
WORLD	FO Licht [45]							829.8	1,047.9	1,397.1	1,540.2
	LMC [47]				530.6	601.6	684.4	838.8	1,078.7	1,405.1	
	REN21 [25]					655.6	697.9	824.8		1,417.0	1,607.3
	Total[e]	*338.7*	*378.2*	*427.3*	530.6	601.6	684.4	838.8	1,078.7	1,405.1	1,540.2
	Minimum[f]	*338.7*	*378.2*	*426.4*	*529.1*	*601.6*	*680.6*	*807.5*	*1,018.7*	*1,328.7*	*1,493.4*
	Maximum[f]	*357.0*	*398.3*	*453.5*	*554.0*	*932.2*	*1,070.9*	*1,290.1*	*1,573.3*	*1,966.6*	*2,062.9*

[a] Total ethanol production based on UNICA [41] multiplied with share of fuel ethanol production as in LMC [47] for 2003 and consecutive years (average).
[b] Based on linear growth of 0.1 Gl p.a. until 2003.
[c] Maximum world production minus minimum country (individual) data on an annual basis.
[d] Summary of selected values (grey boxes).
[e] Summary of selected values (grey boxes).
[f] Sum of minimum/maximum values per country.

pared to data from international sources (see e.g. data selection for the US and Brazil). EU data from EBB [29] seems to be more robust and up-to-date as Eurostat [14] as it is based on annual industry interviews. Furthermore, some EU MS report imports partly as own production to Eurostat since real (neat) imports are blended with domestic production (at a lower blend level) thus artificially increasing the actual national production volume. This might explain EU data variations between EBB [29] and Eurostat [14] in the years 2006–2008. Argentinean production data by FO Licht [45] and REN21 [25] appeared too optimistic. Therefore, medium/lower estimates by USDA [19] and AREC [26] were selected. Emerging biodiesel producers including Malaysia, Indonesia, Thailand, Colombia, and China were grouped in the category 'Others'. REN21 [25] was found to be a reliable data source for most of these countries while data on Malaysia and Indonesia is mainly drawn from FO Licht [45] (see Section 4.1 for a discussion on available data). Data for China and Colombia in 2007 was extrapolated using data from 2006 and 2008.

Data by Dillon et al. [71] on Indonesian biodiesel production in 2008 appears overestimated. Apart from that, annual production data for individual countries varies only slightly across different sources. Summed up however, the range between the minimum and maximum country individual annual data increases to almost 60 PJ in 2009 (see last two rows 'Minimum' and 'Maximum' in Table 11). The key uncertainty factor in this increase appears to be the actual total world biodiesel production, or in other terms the production in emerging biodiesel markets as shown in row 'Calculated upper value' (see Table 11).

The data selected is believed to present a realistic and – where data choices could be made – deliberately 'conservative' picture of the market. It is evident that even under these circumstances the market shows an exponential growth. The production in emerging biodiesel markets was calculated as the sum of production in reportedly active countries, i.e. Thailand, Colombia, China, Malaysia, and Indonesia (as laid out above). To reflect the uncertainty, i.e. the likelihood of not yet monitored but existing biodiesel production, a 10%-uncertainty factor was added to this production (see row 'Total emerging markets'). The 10%-uncertainty factor grows to over 6 PJ in 2009 and by then includes e.g. countries such as India which are reported to have had a production of around 0.1 Gl or 3.3 PJ [25].

The selection of data sources and underlying assumptions on fuel ethanol (see Table 12) were made in-line with those for global biodiesel data. Where possible, the same sources were used (see e.g. US data). Apart from UNICA [41], all data presented in Table 12 is for fuel ethanol only. To derive the amount of ethanol production for fuel use in Brazil prior to 2003, UNICA [41] production values were multiplied with average shares of fuel ethanol production (based

Table 13
Summary overview of US and EU subsidies, tariffs, and duties (US$).

	US$/l	US$/gallon	US$/tonne
US Volumetric Excise Tax Credit			
(Fuel) Ethanol	0.1347	0.51	171
Biodiesel (agricultural origin)	0.2642	1.00	300
Biodiesel (waste oil)	0.1321	0.50	150
Average of maximum support levels within EU MS[a]			
(Fuel) Ethanol	0.3743	1.42	474
Biodiesel	0.3009	1.14	342
US import tariffs and taxes			
Import duty undenatured ethanol (2.5% ad valorem)[b]	0.0128	0.05	16
Import duty denatured ethanol (1.9% ad valorem)[b]	0.0098	0.04	12
Import tax (un)denatured ethanol	0.1427	0.54	181
Import duty biodiesel (4.6% ad valorem)[c]	0.0378	0.14	43
EU import tariffs, ADD and CVD			
Import duty undenatured ethanol	0.2536	0.96	321
Import duty denatured ethanol	0.1347	0.51	171
Import duty biodiesel (6.5% ad valorem)[c]	0.0534	0.20	61
Minimum anti-dumping duties on US biodiesel	0.0798	0.30	91
Maximum anti-dumping duties on US biodiesel	0.2302	0.87	262
Maximum countervailing duties on US biodiesel	0.2756	1.04	313

[a] Own calculations based on EU MS reports (see footnote 15).
[b] Assumed international fuel ethanol price: 0.5136 US$/l.
[c] Assumed international biodiesel price: 0.8222 US$/l.

on [41,47]) in the following years 2003–2008. For the EU, again, industry data (as supplied via the EU ethanol industry association) was chosen. For the year 2004, an average value of industry association data was made. As Table 12 presents, ePURE data [33] is at the lower end of the data range—as found across international sources.

Similar to the world biodiesel market, it is challenging to assess the exact amounts of fuel ethanol production in emerging markets. In contrast to the biodiesel market however, many data sources provide worldwide production data for many countries and subregions (e.g. [45,47]). Whereas data for 2000–2002 was estimated (linear growth of 0.1 Gl p.a.), these sources provide a decent data basis for the estimation of global production including emerging markets.

As in the case for biodiesel, Table 12 also provides a maximum amount of potential production in emerging markets ('Calculated upper value') which in the face of available data seems unrealistic and should only be seen as an upper cap. Also, total world minimum and maximum production levels are indicated. The selected data, as presented in Fig. 1 is again boxed grey.

A.2. Biofuel tariff and subsidy summary

Table 13.

A.3. Conversion factors

1 tonne ethanol	1,267 liters	0.64	toe	26.796	GJ	USDA values
1 tonne biodiesel	1,136 liters	0.90	toe	37.681	GJ	USDA values
1 US$	0.757 €					Oanda.com average for 2004–2010

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